The London Hospital Computer Project

A case study in the installation of a major real-time system

THE LONDON HOSPITAL COMPUTER SYSTEM

A CASE STUDY IN THE INSTALLATION OF A MAJOR REAL-TIME SYSTEM

THE PROCEEDINGS OF CONFERENCES HELD ON TUESDAY, 27TH. NOVEMBER 1973 AND WEDNESDAY, 24TH. APRIL 1974, AT THE LONDON HOSPITAL MEDICAL COLLEGE HALL ASHFIELD STREET, LONDON E.1.

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GLOSSARY

Called File	-	the list of patients to be admitted from the hospital waiting list.
Defaulters File	-	the list of patients who did not attend for admission when called.
Empty Beds List	-	the number of empty beds per ward in the hospital at any one time.
Home Display	-	A screen giving the list of facilities available on the terminal.
Recently Admitted File	-	the list of patients admitted to the hospital on the day in question.
TCI	-	'to come in' i.e. to be admitted to the hospital.
Teletype	-	A UNIVAC DCT 500 printer
Temporary Leave List	-	patients not actually occupying hospital beds at the time e.g. temporarily discharged.
Tree Branching	-	method of building up a message to the computer through a series of screens giving multiple choices.
V.D.U.	-	a Uniscope 100 computer terminal.

INTRODUCTION AND APPROACH

The project that we are going to talk about has grown up over a number of years and it has, I think, been formed by three major influences. The first is an abreaction, against the early casualties of medical computing, secondly an influence which is both frustrating and instructive, but it has produced in the team which has created this project, a passionate desire to build a system which has been designed for the user. The final influence is a concern that above all the system should be credible; credible for the user in the way just described and credible to the outside world which had led to the policy of a complete blanket on any publicity at all until the system was actually up and going. In the following chapters, I think you will perceive many ways in which these influences have had an effect on the project.

The project which has resulted from them has a number of features of interest which we would like to describe. The first is a technical achievement, the second has been a paramount concern with the mechanics of change in a large organisation. These mechanics happen to have been used in this particular instance in the introduction of a computer system throughout the entire hospital. They are capable of translation to other major areas of change and that might be one of the things to be discussed later. Finally, the other major point of interest is a desire to evaluate the effect of the system. A desire partly formed by, and partly to assist an overall attempt, because at this stage it cannot be described as any more than an attempt, to discover in detail how a hospital functions. There are only two points to make; the first is that the entire project has been funded by the Department of Health and Social Security as part of their experimental computer programme. The Department have been exceedingly generous to us despite the fact that, on at least three issues we have disagreed admittedly amicably, but nonetheless very strongly indeed with their original policy and have stuck to our particular point, and we hope have been able to demonstrate in the end that on those partuclar issues at least, we were not totally wrong.

But, despite this, the Department has not, perhaps charitably, concluded that we were grossly unreasonable and they have contined their support. Indeed they have just given us another set of kit, of a value in excess of £150,000. The final point I want to make is that the project that we are going to talk about is essentially a collaborative effort. The team consists of Maureen Scholes, who began as an assistant matron but was happily translated into a senior nursing officer; Professor Bob Cohen who is the Reader in Medicine; Dr. Barry Barber who is the Director of our Operational Research Unit; Bud Abbott who is the only man who understands how the elastic bands inside the computer actually tie up together, and David Kenny, who is the administrator of the project who, I think, has the particular problem in that I piloted the project myself up to a point when the going looked rough, i.e. was about to go live, and I handed it to him and said "You hold it". Without any one of those five the entire project would have floundered. I would like, publically to thank every one of them, not only for the amount of effort that they have put into the project but also for having been so remarkably charitable about the unreasonable way in which I drove the project in the early days. We now get on to what the thing is all about which is a presentation on The London Hospital Computer Project. We begin with Maureen Scholes talking about Key User Decisions.

KEY USER DECISIONS

Mr. Fairey has outlined the principal objectives of our system. Technical considerations will be described by Mr. Abbott later this morning; but assuming for the moment that technical problems are solved and that systems and programming staff are available to build a computer system, I want first to think about what questions need to be answered by the hospital. Which aspects of the hospitals work can be helped at all by a computer system, which can be helped best, and how does one decide on priorities? Who will use the computer system and how can one ensure that it is quick and easy to use? How does one ensure confidentiality of the system? I am going to describe some of the key decisions made at an early stage of the project by the computer executive. The computer executive is the small multidisciplinary group that Mr. Fairey has just described so aptly. It was formed in 1968 and it exists both to control the activities of the computer unit, but mostly to ensure adequate discussion and agreement with hospital staff prior to the installation of computer systems. It acts formally by instructing the unit about applications or by agreeing reports on systems. Professor Cohen, Mr. Kenny and myself are responsible for establishing priorities within our own areas of responsibility and for bringing this information to the executive and interpreting the development of the project both to our colleagues within the hospital and to the computer staff. The three of us, the doctor, the nurse and the administrator are all actively involved in the day to day work of the hospital: in other words we keep our "normal" jobs. We thus have an up-to-date knowledge of the hospitals requirements. Furthermore, since we have to live with the decisions that we make we have a healthy incentive to ensure that the users needs are sufficiently taken into account. The executive meets regularly, we have a fixed half-day a week and on average the doctor, administrator and myself each contribute one day a week to computing. This informal liaison with the hospital is reinforced by a small medical committee which is a sub-committee of the medical council. For nursing staff a small group of senior staff are available for consultation and co-ordination on nursing aspects. These two groups both provide an approval mechanism for proposals and they give advice and opinion. Equally important, their existence ensures that there is a nucleus of senior and informed staff who are vital to successful implementation. The first major decision made by the executive was on the method of approach to the project. There seemed to be two alternatives: one was a pilot study in depth in one or possibly two wards exploring the roles of the computer in all aspects relating to a patient's care and treatment. The second is a modular approach in which one hospital activity at a time across the whole hospital, would be examined and linked with the computer and succeeded by another as the first became operational. With a pilot study one could quickly make progress but we do not fully understand how the different sections of the hospital interact, thus the pilot scheme might not easily be extended to other wards either because the systems are so different or because the system requires too much effort by a small dedicated group just to keep going. Nor we think, can the total effect on the other hospital systems be assessed from a pilot study. There are also considerable difficulties within an organisation when duel systems are operated. We met this in a drug study when we were running two different manual drug administration systems simultaneously. In this case it would be a computer and manual system for the same hospital activity. The most important advantage of the modular approach is that as each activity is implemented there is positive gain across the whole hospital. It is not a protracted experiment, and a wide variety of staff are gradually involved and hopefully grow in expertise with the system as it develops. There are none of the problems of duel systems but there is however one major disadvantage of the modular approach. If the system or the equipment, or the programmes fail to come up to expectation the whole hospital is aware of this and there will be considerable disruptions of the organisation. Nevertheless, we chose the modular approach because although it was more challenging it did seem to have more to offer. Having decided on a modular approach, which activity first? We concentrated on in-patients for the first model. An in-patient system contains many problems and needs; an out-patient system is probably less problematical, but it serves in this hospital an unusually large out-patient department. We have three quarters of a million out-patient attendances per year. We would need much more equipment for less complex problems. For in-patient files, one needs certain basic administrative data before one can organise any computer service for the patient, so our first activity was in-patient administration, and these admission, discharge and waiting list systems will be described later this morning by Mr. Kenny. The first service chosen was the clinical laboratory partly because the automated equipment in the laboratory lends itself to computer application, but mostly because it forms one major aspect of the patient's investigation and treatment. We know that 75% of all of our patients and 100% of our wards use the system, thus any saving of time, any improvement of service should be of immediate benefit to the whole hospital, and Professor Cohen will be describing this system later. Subsequent activities in this first model are in radiology, morbid anatomy a drug interaction dictionary, an extension of the patient index and nursing manpower study. Much discussion both within the executive and the hospital committees and staff has been needed to arrive at these decisions, and the criteria that was used included whether the system was technically possible whether we had got enough staff and enough equipment, whether it met a real need in the hospital and how widespread would be it's effect on the hospital. Model 2 will move into out-patients and thereafter into other systems and other hospitals in the group. Such patient-orientated systems as I've just been talking about must be available practically all the time. Who then are the users and how can we ensure that the system is quick and easy to use? We discarded the idea of using trained operators to input data as happens in industry. We felt that this would involve transcription which is wasteful and dangerous. Our users therefore would be the doctor, the nurse or the clerk directly involved in the patient's care. It would not be acceptable to ask them to spend a lot of time on new and additional tasks made necessary by the arrival of the computer. Therefore the method of communication with the computer has to be simple, quick and efficient and certainly no slower than the manual methods. It has also to be quiet, for example a tele-printer in a ward at night could not be tolerated. We took one to a ward and tried this. We agreed therefore on a visual display unit (a V.D.U.) with a typewriter-style keyboard employing the technique known as tree-branching. We were firmly against codes that had to be learnt and each display format had to be self explanatory and require little or no typing, as most doctors and nurses are unable to type quickly. In tree-branching the user has displayed for him on the screen a list of choices of services. He selects the one he requires by pressing the appropriate key and this presents him with further choices within that particular service, and so a message is built up between him and the computer. We will be talking about the educational effort and the implementation of the system later this afternoon. Finally, how can we ensure the confidentiality of a computer system? Key decisions made about this again involved much discussion as you might imagine within the executive, between the executive and the medical committees and with the medical defence committee. We have two guiding principles: 1) that the computer system should be no less confidential than the manual system, and secondly that the confidentiality procedure shall not be so cumbersome as to detract from the acceptability and usefulness of the system, and so for each new application confientiality must be reviewed. We have to ask, is the information confidential, how many kinds of staff are involved in this paricular aspect of patient care, how many need access to the information and so on. If you adopt soft ware codes or badge readers that allow information to certain staff and not to others you must also assign other staff and design a manual system to effect this. It must continually be reviewed and updated to allow for sickness, holidays, promotion and movement of staff. Even the time of day or night may make a difference to the category of staff who need certain information. We have not adopted soft ware codes we have not adopted badge readers. We at present adopt the following simple measures. The V.D.U. display units are so sited that they are not easily viewed by the passer-by or the patients. Information on the screen fades automatically if the member of staff is called away to attend to a patient hurriedly and has not time to turn off the display. Moreover laboratory information fades more quickly than the lesser confidential information about the bed state or the administrative information. No information from venereal disease clinic will be displayed. This is a statutory requirement, and we do not display the marital status of patients in the gynaecological or obstetric wards. Information from one ward is only visible in another ward to which it is twinned. And it's twin ward is usually an adjoining one of similar nature. It is now part of the contract of employment of all staff that information about patients is confidential so this includes the computer staff as well as everyone else. Lastly and most important, any consultant or his deputy has the option from the time he places the patient on the waiting list to suppress the viewing of all medical information.

TECHNOLOGICAL CONSIDERATIONS

One of the initial problems that the computer executive (referred to by Miss Scholes) had to face was the gap between the system requirements and cash available. As with all the experimental projects the London Hospital was given an absolute ceiling for capital expenditure for the first model of the real-time system. In our caseit was £400,000 and while we were delighted with this amount, we soon found that,as probably all computer scientists find, that it was not enough. We had envisaged an all singing all dancing system that would be all things to all hospital men and while in the early stages manufacturers promised great things we found that, in the end we had to make some compromises. Certainly we bargained hard not only because we wanted a best buy, but probably more important, we had to be as sure as possible that the system had the capacity to support the real-time system that we had proposed. It is perhaps worth remembering that these negotiations were carried on in the period 1968-1970 when the number of comparable real-time systems in the country could be counted on one hand. All were using capital equipment of twice the power, twice the cost and none were trying to set up a large system based on visual display units with the sort of response time we were asking. Indeed the tender contained certain minimum requirements which are probably the best indication of our problem (Fig. 1).

FIGURE 1

INVITATION TO TENDER
MINIMUM SYSTEM REQUIREMENTS.

1) Cost less than £400,000
2) System and batch capability
3) Response time - 95% less than 3 seconds
4) Availability - 98%
5) Operating System for Real-Time
6) Fast direct access storage
7) Specific items of hardware
8) Maintenance guarantee

Just to make sure we did not miss anything we also added a list of desirable requirements(Fig. 2).

FIGURE 2

INVITATION TO TENDER
DESIRABLE FEATURES

1) Availability
2) Response time
3) Communication Processor
4) Electromechanical back up
5) Additional Equipment
6) Expansibility
7) Links for satellite computer
8) Software

It is worth noting that we did not specify particular hardware except in broad outline - effectively, the manufacturers were being told what we wanted to achieve and asked to supply equipment from their particular range that would best fit. Thus it was hoped that the hospital would be able to pick from across the range of manufacturers, the configuration that not only had the capability to meet the demands of the envisaged system but also represented the best buy. In the event, the invitation to tender was followed by a series of dialogues between the various manufacurers and the hospital. This ended with a considerable reduction in the number of tenders. In fact, the number came down to four. Even these four did not meet the original minimum requirements and there was no option but to ask for re-tenders.

Two tenders were re-presented and two of the tenders were changed sufficiently to meet the minimum standards and we began the evaluation of tenders process.

In this evaluation process we endeavoured to judge the four tenders against the specification, both literally and in the spirit. Many areas involved new products, most of the vital software offered was unproven, and there were some very novel techniques proposed for the use of the hardware. Three teams were involved in the evaluation - one from a firm of consultants (SCICON), one from the project team, and the computer executive itself formed a third. Each team proposed a structure for the comparison of the tenders; these in practice proved to be very similar and it was agreed that a common form would be used. Again each team carried out its own evaluation of the tenders using this form. As it have already implied the two tenders that were simply re-presented did not meet the minimum requirements, and were eliminated very early on. Of the two remaining tenders each team finally recommended the Univac tender and the following slides show a schematic of the hardware obtained (Figs. 3 and 4).

FIGURE 3 Univac 418 - 111 Real-Time Configuration

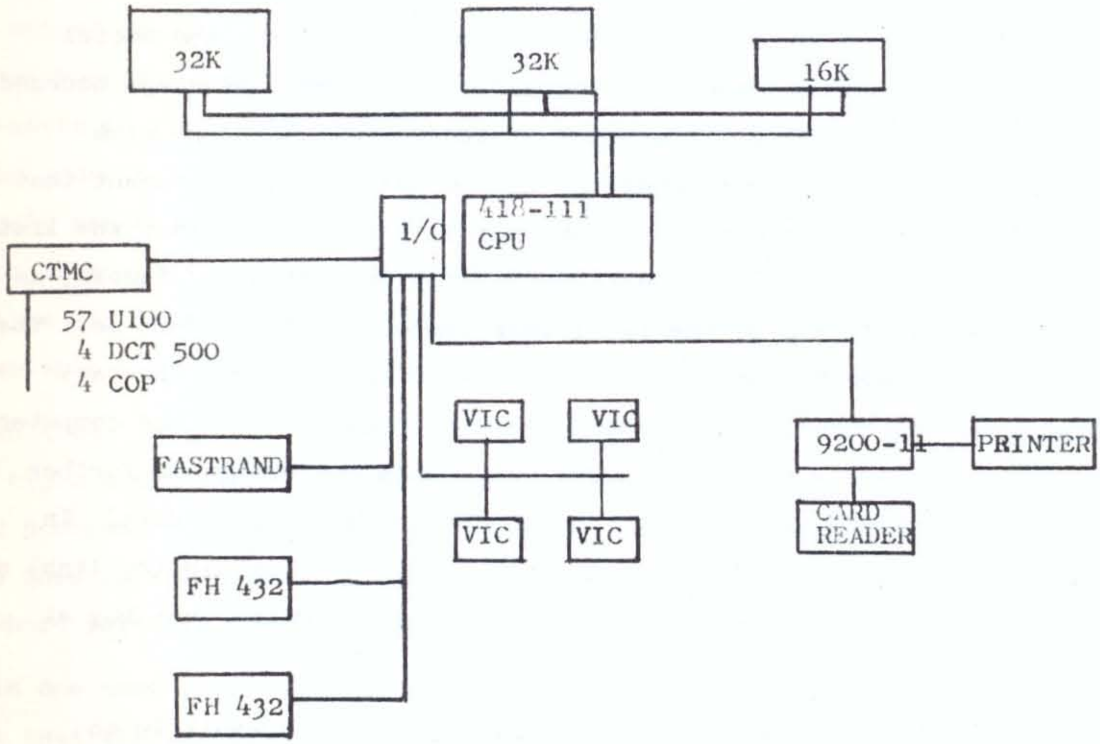
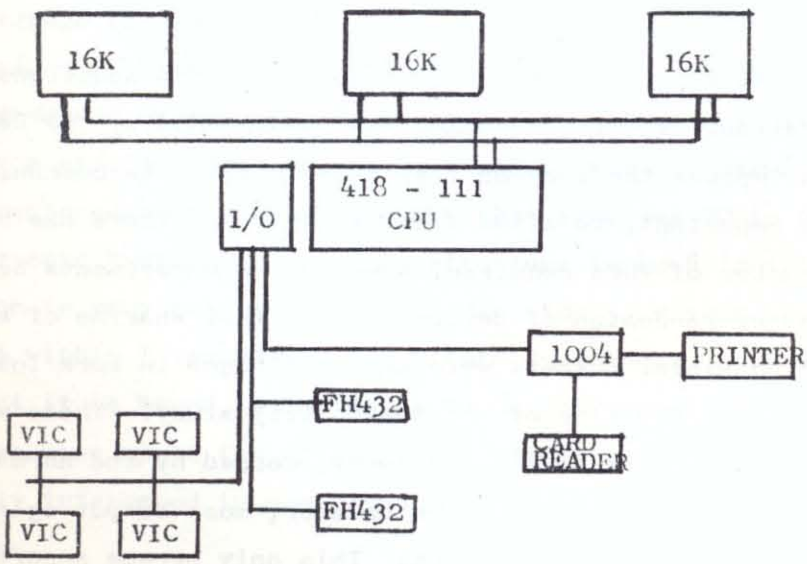


FIGURE 4 418-111 Batch Configuration



The question is often asked - how effective was this tendering process. Looking back with a certain detachment acquired by time, I think there were several advantages gained. First in the field of education: the project team did not have real-time experience and at that time most of expertise (although largely theoretical) was with the manufacturers. The computer executive also benefited from this but probably more important became educated in the curious ways of the manufacturers. Finally, the Department of Health and Social Security very wisely watched and also learned. The second advantage accrued from the inclusion of the list of minimum requirements. Although each manufacturer had to be convinced that the London Hospital really meant that a tender had to comply with each and every point; it did mean that the list of manufacturers was rapidly reduced to manageable proportions. Indeed, as I have already indicated, two of the final four tenders still did not meet these requirements. The third advantage I would like to refer to was the fact that we had a clear consensus of opinion from the project team, the computer executive and the Board's specialist advisers. This consensus was further supported by The Department of Health and the Technical Support Unit. In other words the process produced a unanimity of opinion that, in the light of all the knowledge that was then available to us, produced the best buy at that time.

The next question tends to be - did the tendering process result in the selection of the right equipment? Here one is on less certain ground. Without a doubt the equipment works - there has been a live system in the wards for many months now, and generally this could be taken as an affirmative answer to the question.

At this point it must be stated that there have been some additions to the original configuration. The first change was recommended by the Department of Health, partly to improve the back-up facilities within the communications network and, more important, to allow later expansion. There has been an increase in the number of VDUs required, some due to departments being moved into new buildings or re-design of departments so that sharing of some terminals was not possible. Others were due to changes in work load from the situation pertaining at the time of the feasibility study. These were all changes of an external nature to the equipment, caused by the normal development of the hospital. The major question mark however, must be put against the need to upgrade the core store from 64K to 80K. This only became apparent some months after delivery and acceptance of the installation, when it was found that the three basic areas of software all needed more core. The increase in number of lines in the communications network, to which I have just referred, was responsible for some increases in both the operating system and the middleware but generally the problem was due to under-statement and under-estimation. That part of the operating system that had to be permanently resident was known, but information was lacking about how much core other elements required, and in the event, these elements were understated or even omitted by Univac. The actual design and writing of the middleware was the responsibility of the London Hospital team with considerable advice and support from Univac. The estimates in the tender were based on Univac expertise and these also proved to be under-estimates. Finally, in the application area, estimates were largely based on the London Hospital statements of record and file sizes and again these proved to be under-estimated. The total cost of all these equipment changes was less than 10% of the original total and this, I think, is an acceptable and reasonable margin for an advanced system of this complexity.

Given these changes - can we still judge if the tendering process produced the right equipment? I think the answer is still - yes. Certainly there have been problems but these have tended to be in those areas where the estimates were more in the nature of informed guesses, where the technology was new or where software was unproven, even not specified.

Again one must refer back to the time that the order was placed - the hospital felt that the sum allocated for hardware was absolutely rockbottom for the purchase of a viable system; indeed most of the expertise that was consulted considered that it would be impossible. As it is, the complete communications network has been in operation since last January for 14 hours a day 7 days a week. The average transaction rate for the admission and discharge applications is about 13 per sec. with a peak rate of 14 per sec . Response time does depend to some degree on the type of transaction - obviously the enquiry that involves only a single access to the $4\frac{1}{4}$ milliseconds 432 drums will give a very much faster response than another enquiry that involves 50 to 60 accesses to the 90 millisecond Fastrand. The file structure is such that the second type of transaction is very rare and the response time is within the specified ranges of 95% within 1 second and 98% within 3 seconds. As part of the evaluation of the project it is hoped to include a technical appraisal of the equipment and how it measures up to the original specification. In the end, however, the users are only interested in one thing - does it work? and the answer to that is quite clear.

Reliability of the equipment featured very strongly in our negotiations with the manufacturers. In practice the down time has been well within the overall average that could be permitted. In so far as there has been a problem, it has been concerned with the time to repair a major fault. As I have already said, since last January the real-time system has been running 14 hours a day, 7 days a week and there has been two major faults in this time. On both occasions the time to repair was too long. Now I am not referring here to what a manufacturer would normally call a good time to repair. Univac provide an on-site round the clock maintenance; this is backed by a very good procedure for calling in particular experience and expertise as necessary and I daresay the service given is as good as any manufacturer provides and probably rather better than most. Already the mainteance of the real-time system is supported by a second, batch processing machine. We have manual switches between the various peripherals but is far from a duplex system; there is no major random access, nor communications and the core store is only 48 K. Nevertheless the real-time system is now an integral part of the hospital procedures and as more applications are added any major breakdown of the service will become more critical. Clearly the long term answer must be to establish a fully duplex system.

Another aspect of the single processor problem is the need for testing time for program and system development. Once the admission/discharge system went live,there was a problem of availability of the full configuration for development of the next application. As might be imagined the ten hours during the night when the real - time system was off the air was not all available for system testing. First, there is the housekeeping attendant on the real-time system, some two hours every night are needed for this. Second, there is the time needed to set up the system, half-an-hour every morning for this. Third there is preventative maintenance, half-an-hour five nights a week and two hours two nights a week. Fourth, there is batch processing that is dependent on the main random access files. Suddenly it is apparent that we are down to five or six available hours on the good nights and on the bad nights this can virtually disappear. This is particularly true in the latter stages of systems testing, because it also takes time to set up the real-time system for the testing process itself. A further nasty aspect of this situation is the effect on the programmers and analysts. They find themselves on almost continuous night shifts in order to continue developments and this clearly affects their output both in volume and quality. I am quite sure that the time taken for systems testing has been considerably extended by this fact alone.

We have attempted various alleviations of this problem. The first was to create a test-bed for the real-time system on the second configuration. This has been successful up to a point - individual programs can be tested in a simulated real-time environment and many of the straight forward bugs elimated. Another software solution is to allow batch processing to proceed under the real-time system and to some degree this is being implemented with the Clinical Laboratory application. One would also like to incorporate testing facilities under the real-time system, but this will call for software design and implementation of the most complex and sophisticated programming. The mind cringes at the though of a rogue program under test escaping from the control of the test facilities and creating havoc with the main files. In any event the latter solution would demand more core. Given the existence of the second processor, it would be less wearing on the nerves to upgrade the second machine to equality in store size and use this as the test facility. Certainly we cannot go on expecting programmers and analysts to work such irregular and difficult hours. After all there is a limit to the job satisfaction of working on an advanced project in the service of the community and we do not pay all that well really.

So far I have largely referred to the management of equipment resources, but the basic management problem is of course largely a matter of managing staff resources. The organisation chart is shown on the next slide (Fig. 5)

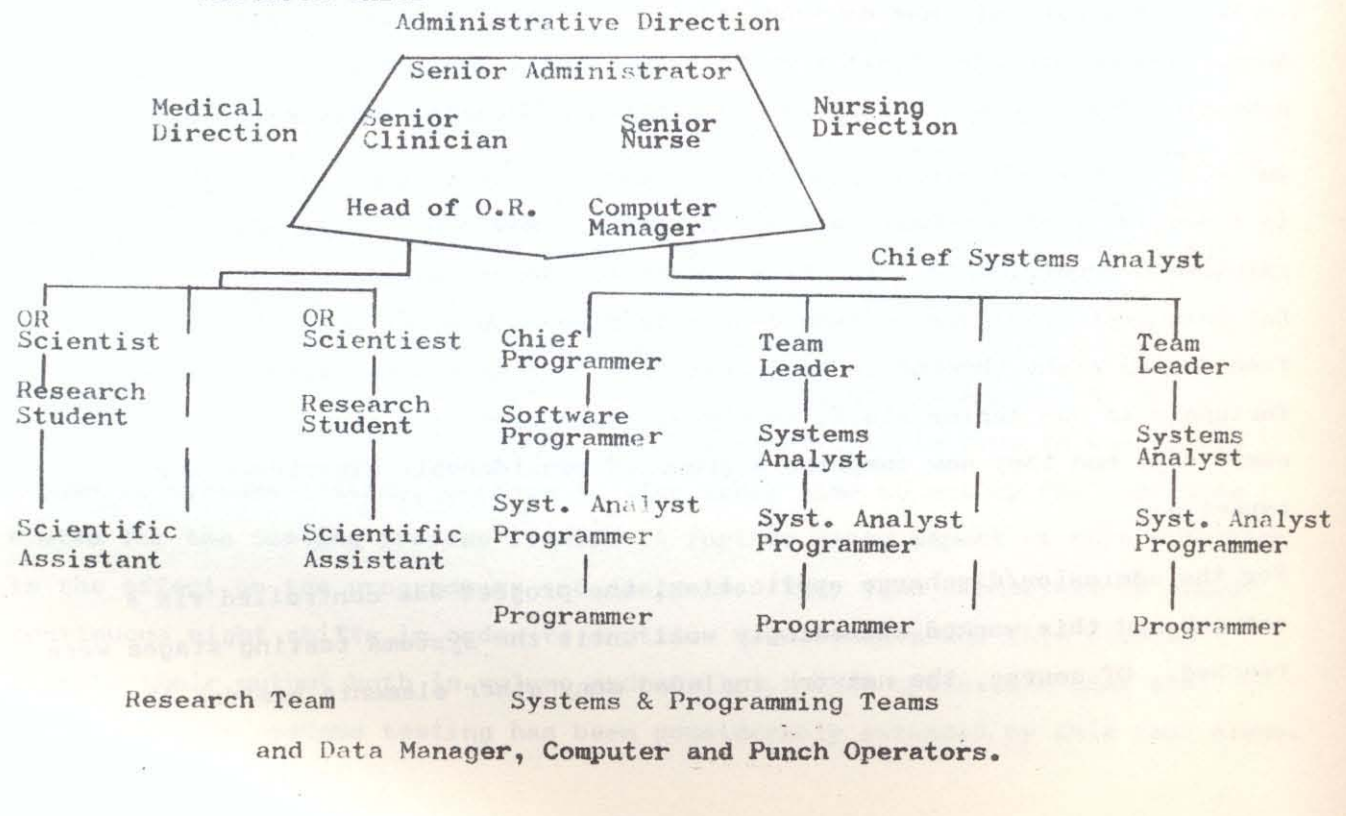
As with all good organisation charts or establishments they are rarely run in the way shown but they do provide a useful basline. In any event the hospital also provides staff for non-experimental project work; finance, operational research and various other batch processing activities.

Quite clearly it is advantageous to run the unit as a complete whole and there is a good deal of movemant between the teams. Moveover, teams are reinforced according to priorities and need. Nevertheless, a basic principle has been kept, viz: that a team leader is responsible for an application from design right through to implementation. We have been exceptionally fortunate in our senior staff, nearly all have been with the project from its early days and they now comprise a group of considerable experience and expertise.

For the admission/discharge application, the project was controlled via a network and this worked exceedingly well until the systems testing stages were reached. Of course, the network included many other elements besides the use of programming and system analysts resources. At that stage we were concerned with matters such as selection, ordering and delivery of the computer configuration; the progress of the building to house the project; the progress of the air conditioning - (I still have sleepless nights over that); the ordering and/or acquiring of other equipment and so on. Basically we found the network kept the executive informed about the progress of all these activities adequately, but was not so successful in the control of the actual development work. Our present method of control is based on monthly progress reports, which are compiled from the resources available in the month and how they were used. This is compared with the forecast objectives and resources for the month; explanations of variations between forecasts and actual performance are given. This procedure is proving to be a more informative method for the computer executive.

Finally, I think it is proper to recognize the part Univac has played in our success. There has always been a good relationship between the London Hospital and its suppliers but in dealing with the main frame computer manufacturers something rather more is needed. All sorts of problems can and have arisen between Univac and The London Hospital but even in the most difficult situations I think it is fair to say that Univac have complied with the spirit and intention of our contracts and agreements - without doubt it has been and is still a most stimulating relationship.

FIGURE 5 The Direction and Staffing of the Computer and Operational Research Units



The waiting list and admission and discharge systems went live in all our wards and main patient administration departments in March 1973. The clinical laboratories system which Professor Cohen is going to talk about will probably go up during the next few weeks. These two distinct applications, the Waiting List, and the Admission and Discharge Systems, together provide the platform upon which the various patient services are going to be built. They do not in themselves make any great contribution to the hospital. They do not save staff nor do they really make more effective our utilisation of resources. Their function is merely an enabling one. Until the patient is accurately identified and tracked as he moves through the hospital it is not possible to order tests for him. The system therefore is designed simply to identify him and trace his progress so that wherever he is, one can straightaway obtain the relevant services.

As applications, they are, I suppose, somewhat uninspiring to behold because all they do is replace the previous manual system in almost identical terms. It is just a straightforward computerisation of that, and although this is an unadventurous approach, it certainly has, for us two distinct advantages. First, by and large, waiting list and admission and discharge procedures consist of a series of relatively straightforward administrative routines. These are capable of fairly easy computerisation and certainly the simplest approach would involve the least change. The second reason is that the manual system was successful and well liked by all the staff. As there were no benefits for the users at this stage (and we had made this very clear at the beginning) why make all the users change to something which might not be so successful, which might be unpopular and which would thus lose us their good-will?

Our aim therefore was first to build up this enabling function while maintaining the prompt service that was necessary in the admissions office; second, to keep the bed occupany above 90% for as much time as we could and third to try and preserve the previous close relationship between the admissions office and medical staff.

There are of course a great many ways of being admitted to hospital even with the highly centralised admissions system we have at The London Hospital (Fig. 1)

FIGURE 1

METHODS OF ADMISSION

Cold Admissions from the waiting list.

Cold Admissions arranged on an ad hoc basis.

Emergency Admissions from out-patient clinics.

Emergency Admissions through the Emergency Department.

Admissions to the wards from the overnight stay ward.

Admissions to the wards from other hospitals

Admissions to private wards.

Admissions to the Nurses Sick Room

Each of these events can itself occur in several different ways. For instance a patient admitted as an emergency from Out-Patients might go directly to the beds of the Consultant under whose care he currently is, or might instead go to the beds of the Consultant responsible that day for emergency "take". Depending upon the doctor's knowledge of the system, the patient might be sent straight to the wards or in fact go via admissions office. He might at other times have to be routed through the Accident Department. Some of these variations are undoubtedly due to misunderstandings or manipulations of the system. But many are logical and based on such practical grounds as the geography of the hospital. The system therefore had to allow for this sort of thing and we took considerable care to avoid changing our procedures too much just because a computer was planned. A further consideration in design is that each activity creates an immediate requirement for information in a number of different places. An admission from Out-Patients immediately needs to be known by the admissions office so that they can adjust the bedstate, deal with general enquiries about the whereabouts of the patient and avoid sending for the patient to come in for admission when he is already in the bed. Medical Records need information for notes and appointment procedures, the nursing office need it for bed/nurse allocation, and Emergency Department and the Admissions Office both need it in order to manage the bedstate for that day.

These then were the constraints. What does the resulting system look like and how does it work?

Well, first I would like to take the waiting list applications. These include all the activities which lead up to the actual admission of the patient. Naturally, one starts with the decision to put the patient on the waiting list. About two thirds of our admissions here are cold. The decision then is normally taken in the Main Out-Patient building. There will be somewhere between 10 and 12,000 a year.

The procedure is as follows: The doctor completes the medical section on a special form, he puts it in an envelope and sends it with the patient to the "to come-in" (TCI) desk, in the Main Out-Patients hall. The carbon copy of form is kept in the notes. The doctor fills in just basic patient data. The patient's address and so on he can leave but what we do want from him are, first of all, the name of the Consultant, secondly the patient's surname and if possible the record number although here the labelling system can take over. Other options are data suppression, the degree of urgency and any preferred date for admission. We would also, obviously, like diagnosis and reason for admission. There is then quite a lot os scope for optional entries, medical comment, investigations needed on admission and any adverse drug reactions. This form is put in an envelope and sent with the patient to the (TCI) desk in the Out-Patient Hall. (See Fig. 2). The clerk, at this desk completes all the administrative data, verifies it with the patient and enters it direct into the computer through the VDU at her desk. (This is one of the few situations where there is any substantial amount of textual imput and it is handled by someone who is used to using the machine and used to typing on it. Nearly all the other messages to the computer are built up using the tree-branching technique referred to earlier by Miss Scholes). When the clerk transmits this information about the patient it is added immediately to the Consultant's waiting list in the computer. If urgency has been specified so the name will go to the correct place towards the top of the list, otherwise pati nts' names are in order of addition to the list. You will remember that sensitive data which the doctor wishes to have suppressed will not be viewable from any visual display unit around the hospital. The patient's name is then retained on the list and this can be inspected from the Admissions Office, Out-Patients, Nursing Office, or from any ward in which that particular consultant has beds.

The doctor, when he wishes to inspect his waiting list, first of all presses "Home Display" (Fig. 3). He selects from there, first of all the Waiting List Services. This immediately gives him the various alternative lists within the waiting list services (Fig. 4).

FIGURE 2.

THE LONDON HOSPITAL WAITING LIST ENTRY

Doctors are requested to complete only the RED portions of this form. PLEASE USE CAPITALS THROUGHOUT
On completion of the RED portions fold and place top copy in envelope
Detach the bottom copy and insert in the Patient's notes
If this Patient is for entry to a Waiting List other than at THE LONDON HOSPITAL specify other HOSPITAL

Consultant:

Record No:
SURNAME:
First Name:

Affix label here if available

Date on W/L (D M Y)

Child bed? YES/NO *
*Delete inapplicable

Patient Address: (L1) (L2) (L3) (L4)

Patient Phone No. (Home):

Phone No. (Business):

Date of Birth (D M Y)

Sex: M F *

Marital Status: S M W D Sp *

Religion

Short Notice? YES/NO *

Admission Comment
[e.g. Holidays,
Transport Required]

N.B. If Transport Required please indicate sit, stretcher or walking

G.P. Name

G.P. Address (L1) (L2) (L3) (L4)

G.P. Phone No.

*DELETE INAPPLICABLE

V.D.U. MEDICAL DATA SUPPRESSION YES/NO *

Urgency: VERY URGENT / URGENT / SOON / WAITING-LIST (Ring Applicable)

Initials Admitting Doctor:

T.C.I. Date (If known): (D M Y)

Ward (If T.C.I. Date known):

Diagnosis/Reason for Admission:

OPTIONAL ENTRIES:

Medical Comment:

Investigations on Admission:

Adverse Drug Reaction

FIGURE 3

HOME DISPLAY

10. Waiting List Services

30. Admissions and Discharge Services

41. Patient Index

80. Noticeboard

95. Demonstrations

Enter Selection No..........

FIGURE 4

WAITING LIST SERVICES

10. Waiting List Inspection

30. All Services

40. Called File Inspection

47. Called File Inspection (Ward)

Enter Selection No...........

(Under waiting list inspection is the "Recently Admitted" file which I will touch on in rather more detail later.) All the operator needs to do is to enter the selection number of his choice and he then sees the list of other hospitals or Consultants. On this occasion we choose to inspect Professor Cohen's female waiting list (Fig. 5.).

FIGURE 5

R. COHEN W/L INSPECTION FEMALE LAST PAGE

Urg.		Name		W/L No.	Diagnosis	Age	C	Date
*	10	A	B	61KH	Hyperlip Upper Wds	55	+	Nov. 73
*	11	C	D	61MI	Uncontrolled Hypertension	57	+	Sept. 7
	12	E	F	63PW	Varicose Veins Op.	52	+	Oct. 73
	13	G	H	41TS	Re-admit	76		Oct. 73

The most urgent patient that has come on to the list at a later date had in fact come to the top. The next most urgent follows, and then the subsequent patients in order of addition to the list. If the doctor wants to get further details of the patient he goes first to administrative data, if he is looking at it from the admission office, or in the ward, he will end up with the medical data first. This gives basic indentifying details. Having checked over this ground he can then make further choices from his waiting list or he can inspect his male waiting list.

Admissions and delections to the waiting lists can only be carried out by theAdmissions Office or TCI desk and the patient's name will remain there until it is time for him to be admitted. When it is decided to admit the patient, the doctor, after inspecting the list in the ward or wherever else it happens to be, fills out another small form which he takes to the admissions office. There the Admissions staff, if the bed is going to be free, operate the call facility on their own visual display unit and the computer prints the letter in their office asking the patient to come into hospital on a particular day. The computer transfers the patients name to the "Called File". Again, this can be inspected from the wards, admissions and TCI desk, and can be amended for cancellations or delays in the admissions office.

If the patient defaults his name is transferred to the Defaulters File. In a similar way this can be inspected, amended and acted upon and, in the latter instance, the computer automatically prints an appropriate letter.

When a patient confirms that he can accept the bed he has been offered he is given an arrival time for the day for which he has been called. This again is entered into the computer and when the patient arrives at the reception office, the reception clerk immediately can admit him, and his name and all his identifying details are transferred to the second system, the Admission & Discharge System.

Not all patients of course reach this particular point in the manner I have described. For example there are unplanned or emergency admissions. For these we have to arrange alternative methods of data capture. There is in the Emergency Department a small abbreviated input screen which needs only the name or a pseudonym for the patient and an assigned record number and the sex of the patient until such time as the patient's proper identity is worked out.

There are two exceptions to the rule, that only the admissions office or emergency and accident department admit patients. These are the Private Wards where a conventional approach to obtaining data is ineffective and in these cases it is possible to put the data in when the patient arrives. The Maternity Wards are the other exception. The propensity for mothers to arrive after office hours requires us to have an immediate "admit" facility for these patients and they are therefore held on the maternity ward's equivalent of a "Called File", but without a date. When the patient arrives only one simple transaction is required to transfer that patient's name to the admission and discharge system.

Admission & Discharge System oddly enough is not as complex in appearance as the waiting list system. There are one or two simple choices (Fig. 6)

FIGURE 6

ADMISSION & DISCHARGE SERVICE FOR MATRON'S OFFICE

13 Cambridge - Bed Allocation

20 Inspect Patient Minimum Details

21 Inspect Patient Administrative Details

22 Inspect Patient Medical Details

23 Inspect Empty-Beds List

25 Inspect Temporary Leave List

27 Cambridge Clearance

30 Patient Index

Enter Selection No..........

One can inspect various categories of patient details - these appear on 20. 21. and 22. The Empty Beds List I shall explain later and the Temporary Leave List is a necessary addition so that one can keep track of patients who may not be in bed at this time but whose beds have got to be reserved. Patient Index I will also deal with later.

When the Reception or Admissions Office admit the patient, his name immediately appears on the screen in the ward to which he is to be admitted. If the patient has arrived in the ward and has not been allocated to a particular bed, for the moment that patient will appear in what we call a "50 bed", and the patient's name will remain there until the ward staff allocate the patient to one or other of the empty beds.

The importance of this numbering will be dealt with later on by Professor Cohen. The procedures for admission/discharge as far as the ward staff are concerned are really quick and simple. For example the staff can transfer the patient from bed to bed, they can transfer him to another ward, to a specialist unit and through the same facility they can also discharge him. The sequence of discharges, again, is simple, and the member of staff, whether it is a clerk or a nurse simply goes through three verification screens and then selects the appropriate mode of discharge. When the patient is discharged his name is retained on the Index which is a cumulative list of all the in-patients who have been registered since the system went live.

Experience so far.

That is an outline of what the user sees for the Waiting List and Admissions and Discharge Systems. What have been our problems? Perhaps because it was a straightforward series of administrative procedures centralised, and by accident of history, already closely studied, the translation to the computer required very little change of method. This must have limited the scope for disaster. Although the changes have been minimal there has been some minor loss of flexibility and we have had to deal with this as it comes. For example one firm wishes to be able to compile its list on the basis that both the urgency and the time to be admitted - in other words "very urgent must be admitted in November" - should appear simultaneously. After a while we have been able to work out a solution to this but it certainly takes time. Our second difficulty is, that we do not think we are entirely successful in ensuring full use of the TCI form. I think this is because it is, after all, a form. The system can work with minimum data and it has not ground to a halt simply because the doctor has not provided all the information that he should have done. But we would prefer him to make proper use of it because we do feel that currently this is something of a lost opportunity. It also has the additional hazard that the few doctors who do use the system properly tend to become disappointed because the clerk is so unaccustomed to it that she does not do it accurately. There are also times when the Emergency Department is busy at night, and data may not be entered promptly, or indeed accurately. This tends most often to happen just when the clerk's duty period comes to an end at 10.00 p.m. - a busy time for an Emergency Department in Whitechapel. The nursing staff are naturally loath to break off from their current duties in order to put in data and we are going to have to find some way round this either by altering the clerical hours or by some other means to make sure that the data does go in at that point. There is also, and this caused the Administration quite a lot of concern, some loss of contact between the admissions office and the medical staff. The strength of the manual system was the continuing close personal relationship between the medical staff and the Admissions Officer. Now the medical staff do not select the patient in consultation with the Admissions Office. Decisions as to which patients are to be selected are made on the ward, so that the Admissions Officer tends to be faced with a fait accompli and it is a little difficult to get people to change their minds at that stage. This is all right at the moment but we feel that the loss of personal contact may make it more difficult to obtain co-operation during a bad patch and we will no doubt be able to assess how serious this is during the coming winter (1973/74).

In the wards we have two problems, it is possible in the case of a patient brought straight from Out-Patients for his details not to be entered at once. This is particularly likely to occur after the ward clerk has gone off duty. Secondly on some occasions the patient may appear to occupy the "50 bed" for too long. Some wards were not as punctilious over this as we would like. These last two points do not worry us too much because we think that the onset of the Clinical Laboratory System will encourage people to complain. One important and entirely unforseen advantage that we certainly did not forsee is that the Ward Sister can now inspect the waiting list. With a centralised system she did not often get the chance of doing this. She derives considerable satisfaction and I think, genuine value, in being able to inspect both the Waiting List and the "Called File" so that she knows which patients are coming. Often, in the past she did not, but now she can make plans if only mentally, to prepare herself for the re-admission of her favourite patient. It also means that she has an opportunity to be present when these decisions are being made and I am sure this is a step in the right direction.

We have two further hybrid facilities which are unexpectedly popular. First there is the "Recently Admitted File" which holds in date order of admission, the names of all current in-patients. This replaces a card index system which was used by the Accident Department clerks and the Telephone Exchange when dealing with enquiries about the whereabouts of patients. It is proving extremely versatile, it is faster and more reliable than the old card index which quickly got out of date and the traffic on it is so high that presumably it is fulfilling an unforseen need, while not presenting the operators with an unmanageable workload. Indeed those of the staff still with us who used the old system, go out of their way to say what a useful addition they find it. Another thing is that the Patient Index, referred to earlier is an accumulated list of the names of all patients admitted since the system came live. At the moment it only covers in-patients or those who are about to become in-patients but it will include Out-Patients in phase 2. One can interrogate it simply by putting in the name and sex of the patient. It will immediately display this name or if there is no direct match, a list of those who most nearly correspond to it. Again it is fast, accurate and it is very popular with the office staff who infinitely prefer it to the previous arrangements. It is also used in other patient administration offices other than the Accident Department and the Admissions Office where we first wanted it, so on quite a broad front this is an occasion where we had not appreciated that there was a need for this type of information. Lastly, the most useful addition to the manual system is the Empty Beds List (Fig. 7).

FIGURE 7

EMPTY BEDS LIST INSPECTION

Ward	Beds	Ward	Beds	Ward	Beds
Buxton	2	Harrison	4	Turner	3
Cambridge	0	H. Raphael	1	Upper	0
Charrington	5	Marie Celeste	3	Wellington	6
etc. etc.					

This shows on one screen an up-to-date list for the whole hospital. The advantages of this, perhaps, are more attractive to the management than to the user so I am not sure whether we can properly claim user popularity for this. Bed-hoarding is, if not a science, certainly a well developed art. Previously, if we wanted, during a difficult time to find out exactly what was happening we had two alternatives.

Either one spent 25 minutes on the telephone, getting an answer which might not entirely accord with the truth, or two people spent half an hour each, tramping around the wards in order to get an accurate physical count. We can now get this picture in the space of 15 seconds. It is in fact the longest response time on the whole system. But in 15 seconds that information is available.

We are still in the process of tidying up a number of the spin-off features.

The bed-state statistics for example are not yet automatically recorded chiefly because the shortage of systems and programming staff has meant that the timescale for some of the additional features has been extended. However, we hope to finish these within the next couple of months. I think we can say that the system is working. It does its job more efficiently than the manual system and has caused, initially, no disruption. It has even produced some distinct improvements. It is a cautious first step but I think for both the users and the operators the going seems reasonable underneath.

CLINICAL LABORATORY SYSTEM

As far back as 1968 when decisions were being made on the order of implementation of applications in the computer systems, there was no argument, either in the computer executive or in the rest of the hospital, that the clinical laboratory system should be the first to follow after the administrative system that you have heard about. This morning the Microbiology request and reporting system is receiving its final testing and is going to go live within the next week or so, Chemical Pathology and Haemotology expected to be live within the next year.

The fundamental objectives of this system were agreed at the start with the clinical laboratory consultants and the computing Sub-Committee of our Medical Advisory Body; they have not appreciably changed over the past three or four years. The advantages that it is hoped will be made available to the clinicians in the ward are as follows. The most important is decreased transit time, this being the interval between making a request to receiving the answer in the ward. The present state of affairs with regard to transit times is not very good in the hospital, and Dr. Barber will give you some facts on this, later this afternoon. The next advantage is that the system will enable the display on the VDUs in the wards of the progress of a test, including the results. It will also allow one to look up and see not only if there has been a result produced but whether the test has in fact been requested and if it has been requested, whether the specimen has actually been collected. This should prevent much unnecessary telephoning and visiting of the laboratory by the house officer. In addition, the practice of writing a second request for the same test if one is not quite sure whether the specimen really reached the laboratory, should stop.

Results will be available on the VDU arranged in several ways. For example, the latest results from a particular patient or the results of a particular test with previous results of that type of test listed in addition. We will also be able to have listed several different types of test on the same VDU screen so that the chronological progress of each of these variables can be compared. Cumulative reports will also be produced for inclusion in the patients record. Other advantages including computer production of labels for specimens, and a ward VDU list of outstanding specimens for collection.

The advantages which will accrue to the laboratories are as follows. First of all, identification will be complete and legible. There will be lists for specimen collectors to work from. There will be a logging in procedure at the laboratory office to record the receipt of specimens. There will be a facility in the clinical laboratories for displaying the backlog of work for each type of test.

There will also be automatic production of work sheets. Further advantages for the laboratory are the automatic production of reports and improved quality control procedures; Organism prevalent reports will be generated from the results of microbiology tests.

There is no doubt that some of these objectives could be obtained by non-computer methods or by less complete computer system than we are implementing. But basically we are anxious to discover whether the large amount of previous work has been done on one or more of these objectives, could be consolidated into a workable, complete 'request to report' system. We could not really see how the complete system could be done other than by a computer aided system. I propose now to go through in a little more detail the actual events from the generative of a request to the production of a report. First of all, a request is made on the VDU in the ward. This results in the generation of collector's lists which also contain computer printed labels to put the specimens. After collection the specimen arrives in the laboratory and is logged-in. The computer compiles a worksheet and the tests are then turned out. Now let us look at how requests are actually made. I propose to go quickly through a series of slides of successive screens which the houseman or other person making the request will bring up on the display unit. Firstly the 'home display' screen will appear on the ward VDU and the item 'clin lab. tests', numbered 51 is selected (Fig.1). The next screen in the series is a list of names of patients in the ward concerned, and we select the patient in question (Fig. 2). The Next screen to appear is an option list of clinical laboratory facilities (Fig. 3). Let us suppose we are ordering plasma area and electrolytes, we select "Blood Biochemistry" and are presented with a list of available tests in this field from which we make the apporiate choice (Fig. 4). The verification screen is the next to appear, this contains all the data for the patient in question, together with the details of the test requested (Fig. 5). There are options for accepting, reselecting or changing the details of the test. We do not think the actual requesting part of the system will be either much slower or much faster on the average than in the old manual system. We have not raised expectations that requesting will be faster, but have represented the new requesting system as an enabling measure to achieve the other objectives I have outlined.

FIGURE 1

Home Display - General Wards

10	Waiting List Services		Pathology Services
		51	Clin. Lab. Tests
	Admission and Discharge Services	52	Late Entry Requests
21	Bed Allocation	53	Progress of Requests
22	Entry of Inter-Ward Transfer	54	Specimens List
23	Patient Discharge (not temp. leave)		
24.	Inspection of Minimum Details		
30	Other Admission & Discharge Services	95	Demonstrations
41	Patient Index		Enter Selection No..51...

FIGURE 2

Sophia   Clin. Lab. Tests ,   Page I

1	16	
2	17	
3	18	
4	19	
5	20	
6	21	
7	22	Smythe-Thomason, Jeffrey
8	23	
9	24	
10	25	
11	26	
12	27	
13		
14		
15		Select Patient Bed No..22....

FIGURE 3

Smythe Thomason, Jeffrey   Page 1 of 1

1	Blood Biochemistry and Organ Function Tests	9	Clean MSU Culture
		10	Other Urine Tests
2	Urine Biochemistry	11	Sputum Culture
3		12	Trap Sputum Culture
4	Blood Group Serology	13	Wound Swab Culture
5	Haematology (Cellular)	14	Other Swab Culture
6	Auto-Immune Disease Tests	15	CSF Tests
7	Serum Antibody Tests (including syphulis)	16	Faeces Tests
		17	Other tests
		77	Regular ITU Tests
8	Blood Culture	88	Dialysis Tests

Enter Selection No..1...

FIGURE 4

Blood Biochemistry (Up to 4 choices) Page 1 of 4

1 Electrolytes and Urea
2
3 LFT
4
5 Alk Phos
6 Total Bilirubin
7 Direct Bilirubin
8
9 Calcium
10 Phosphorus
11 Magnesium
12
13 Acid Phosphatase

15 PP + Alb + Glob
16 Fibrinogen
17 PP Strip

99 Type Name of Test Required

) 1 + 3 + 11..........

FIGURE 5

Clin. Lab. Request Form	Smythe-Thomason, Jeffrey
Record No. 12345-57	Age 54 years Sex M
Consultant	Dr.
Investigations	Blood Biochemistry
	Electrolytes + Urea
	LFT
	Magnesium
Relevant Diagnostic Data	None
Relevant Drug Therapy	None
Specimen Collection Due	1 January 1974

1= Accept 2 = Reject 3 = Change Data)1____________

Let us suppose that the request we have made is a routine request, i.e. one requested today, for collection tomorrow morning. The computer holds the request until 2.00 a.m. tonight and then it produces lists for specimen collection, arranged by wards. These lists are, in fact, computer-produced request forms, which also contain peel-off printed labels for the specimens. These request forms also function as a laboratory document for those particular laboratory activities which do not operate from work sheets.

It also serves as a fall-back form because there is a space to insert the results so that the form can be sent back to the ward if the computer reporting system should fail. These request forms are delivered by porters to the appropriate wards, the specimen is collected, labelled and taken to the laboratory office, where the specimen is logged on a laboratory VDU as having arrived. This logging in procedure has three effects. Firstly the fact of the specimens having both been requested and delivered to the laboratory is stored in an appropriate computer file whence the fact can be accessed by the ward and the laboratory VDUs. Secondly, the request is added to the laboratory work backlog file which can be looked up on the laboratory VDU, and thirdly, the request is added to a computer held work sheet for tests which are run on a work sheet basis. The work sheets will be printed out on demand by the laboratory teleprinters.

The subsequent steps in the system are as follows:- for autoanalyser tests, the results are computed by a Modular satellite computer, using a system developed by Professor Peter Griffiths at Dundee. The results are then transferred from the satellite to the main computer; in the main computer quality control procedures are performed and, if acceptable, the individual results are inserted into the basic computer held basic patient record. These results can be looked up from the VDUs in the ward. The consultant or the appropriate person in the laboratory can also access these results from the main computer for approval; until he has done so the results which are viewable on the ward VDU are flagged as 'unapproved', in addition to this system a hard copy report is produced every twenty-four hours for those patients who have had a test result within that 24 hour period. This ia a cummulative report specially filed in the patient's notes. Results which are produced in the laboratory by manual procedures are entered on special formats on laboratory VDUs, to be subsequently processed in the same fashion as automatically produced results.

Now how do we look up the results of a test from the ward; a similar tree-branching system to that used for requesting a test is employed. This initially results in a list of tests in progress for an individual patient, showing the dates on which the test was ordered, the specimen received in the laboratory, the result available on the VDUs and the cumulative report printed; if a report is available the next screen will display it. (Figs. 6 & 7)

FIGURE 6

Smythe-Thomason, Jeffrey 12345-57 Page 2 of 3

		Dates of Req.	Spec.	Res.	Rep.
6 C 160006	Blood Biochemistry	30 Jul.			4 Aug.
7	Elect + Urea		3 Aug.	4 Aug.	4 Aug.
8	Magnesium		3 Aug.	3 Aug.	4 Aug.
	Acid Phosphatase		Cancelled		3 Aug.
9 M 090007	Microbiology	1 Aug.			5 Aug.
	Swab Culture		---	4 Aug.	5 Aug.
	Lgr Side Body Drain				

90 = Other Patients, 91 = Request Tests 92 = Options
Item No. to view details, or cancel, or print) 10

FIGURE 7

Smythe-Thomason, Jeffrey 12345-57 M090007 Page 1 of 2
Specimen Collected 2 Aug. 1972 Checked in...........

1 : No growth obtained
2 :
3 :

	Pen	Stre	Tetr	Gent	Meth	Eryt	Amp	Ceph	Sept	Nyst
1	:	:	:	:	:	:	:	:	:	:
2	:	:	:	:	:	:	:	:	:	:
3	:	:	:	:	:	:	:	:	:	:

Growth Culture (Key ***Profuse * Fully Sen - Resistant)

90 = Print 91 = Other Patients 92 = Request Tests
93 = Requests in Progress List) 92

I have not dealt with many features of this system, for instance how late requests and urgent requests are dealt with but perhaps this can be brought up in the discussion. I should however say that in the present model of the computer system the procedures which I have described refer to in-patients.

For out-patients, requests are made on manual request forms specially designed for easy transcription into the VDUs by trained operators in the laboratory office. Obviously the cost of having VDUs in all the doctor's consulting rooms in out-patients would be prohibitive.

Clearly we cannot make any objective comments about the likelihood of success of this system at the moment. However, you might like to know some of the mistakes that we have made during the development of this system. We initially tried to conduct the system study on exactly the same lines as that which was proving successful for the administrative systems, i.e. by sending a team leader into laboratories, directing him to detail the system and presenting it to the users both in the laboratory and the wards. This method failed because unlike the administrative systems there were three separate divisions in the clinical laboratory, namely, Chemical Pathology, Microbiology and Haematology, operating independently in many ways but inter-dependently in others; and interactions were just not covered adequately in the system study produced. So we ended up having to form a clinical laboratory working party in which the laboratory consultants, chief technicians and the systems staff met at frequent regular intervals; in this way much faster progress was made. It was obvious that the lesson from this was that the exact method of approach depends on the nature of this system and the particular environment in which it is to be set. The second mistake, which was mentioned by Mr. Abbott this morning but which I must belabour again, was that the time required for systems testing was underestimated. Matters were made difficult by the fact that there was a live system already present and Mr. Abbott has explained to you how this night working becomes rather anti-social for the people concerned with it, but in the near future things will be speeded up since facilities have been provided which will permit testing a parallel with live activity. The third mistake may be of some interest to you as an example of a typical pitfall. This was not really so much a mistake as a misunderstanding. The systems description concerning the format of the hard copy cumulative reports was written in such a way as to leave the clinicians thinking it meant one thing in terms of arrangement of cumulative reports whereas the systems staff who wrote it implemented something entirely different. When this misunderstanding was discovered by pure chance, it was clear that a hard copy report format proposed by the computer team was quite unacceptable to the clinicians. This may seem something easy to put right, but it necessatitated a major re-organisation in the way in which results were stored in the computer files; it took the laboratory team about two months to put this right.

A. EDUCATION

Despite the fact that our system is easy to use, the educational effort has been considerable and it really is easy to use, but one should not underestimate the effort needed to implement a major change in a large and complex organisation. We were influenced by experience of implementing changes in the hospital. I touched on this this morning when I mentioned the drug administration system. We knew that we had to get the senior staff committed and also that the junior staff should genuinely understand the system, see it's benefits and have full opportunity to ask questions, which they, and not the executive, felt were important. We thus set about, we hoped, on creating the right sort of climate of opinion. We began in 1969 with a series of one day sessions, for senior, medical nursing and administrative staff. They were whole days and we had about 15-20 people (preferably about 15). The day consisted of a broadly based computer and systems appreciation course leading to a description of the project. Food and refreshment was served in the same building so that discussions between the computer executive and captive members of the staff could continue without interruption. These days were very much a two-way process for the executive were provided with a wealth of helpful information and advice. Then we followed these by a half day session for the Registrars and the Sisters. We used Sister's study days for these. Lectures were arranged for medical students and every set of student nurses in training. These still continue for every set of student nurses in training. By 1972 the second phase of the educational programme had begun. These were intensive sessions for all those staff who would themselves use the first application, so it meant most of the ward nursing staff and the ward clerks. We took, in fact, groups from pairs of wards across to the computer centre where there were VDUs and the ward staff were trained using specially designed demonstration programmes. They each worked for about an hour through a serious of tests, where they moved fictitious patients into a numbered bed, moved them to another ward, discharged them looked up laboratory results and so on. There were simulations of the waiting list, admission and discharge and laboratory systems. There was also a none too easy game called Nim, which I suppose many of you know. Each member of the staff was given a carefully designed handbook and you have all got a copy of this. This essentially tells one how to start using the system, how to stop and what to do if it goes wrong, and it describes some of the applications in detail. Lectures take place for new members of the trained staff; every new ward clerk, and every new nurse or sister has a session in the computer department during their induction day and again, this takes about one hour. Mr. Kenny is now going to talk about the implementation of this.

B. IMPLEMENTATION

Miss Scholes has described the build-up to implementation. This was the culmination of a process of change. Those of you who are familiar with the work of Professor Revans will know of the proposition, that if the speed of learning in an institution or a society does not keep pace with the rate of change the result is chaos. The speed of change is at its fastest and shortest during the process implementation. Realising this, and also still being very aware of the conscious decision we had taken in going for a modular approach, that is, implementing right across the hospital, instead of the pilot approach in one restricted department, we knew that not only would this change happen quickly but that the feeling that it was going to be a failure would also be apparent with the greatest speed. Added to this was the experience that Miss Scholes and I have had with the drug system which she referred to earlier. The system of prescribing and administering drugs was changed throughout the hospital. This turned out to be a difficult thing to plan but extemely likely to implement. We had all the problems of duel systems which we talked about earlier on, we had all the problems of learner resistance and we had all the problems which come with not being able to predict the precise impact. Although in a sense our previous experiences at this hospital had moulded and influenced our approach, it also was adding significantly to our anxiety.

Our approach was this. The VDUs were first of all installed some weeks before the system went live. The installation of a VDU in a ward in any case is an excellent conversation piece if only in terms which way it should face, so that the staff, I think, felt they were brought in at that point. Secondly, the handbook which we have, whose structure and design owes much to Kay, Sime, and Dodd on Programmed Learning, was issued to all the staff who were likely to come in contact with it. As well as that handbook detailed guidance notes were issued to the ward clerks, the student nurses, the staff nurses, ward sisters and the admissions office staff who were coming in contact with the system. No matter how much they already knew about it we presumed that they had not had explained to them precisely how today's activity would be different to tomorrow's. The waiting list with some 2,000 odd patients had to be transferred from the card index to the computer system. This was an awkward job ecause transcription is always prone to errors. We also, by popular request, started on a Tuesday. We decided also that the input of the current patients should be carried out by the staff so that they were able initially to get some quick feel for the system. We had also carried out a number of morale-boosting visits a few days before every implementation.

The main problem was how to change habits in 30 wards without causing too much disruption bearing in mind the need for further additions with subsequent systems. We eventually decided to provide continued advice in the wards. When putting in the drug system we discovered that the supply of information during this process needs to be of two types. First of all straightforward instructions. No matter how much information is put out one needs to be able to provide the instruction there and then because it is only when people's hands are on the real thing they think of the right questions to ask. Secondly, there had to be a sort of referee function to explain things as they went along to prevent too much courageous innovation on the part of the learners. Perhaps for both of those it was very important that this had to be immediate. There is no point at all in saying "That's fine, we'll give you the answer tomorrow" or"someone will come along and see you". The answer had to be available there and then so eight members of Mr. Abbott's staff and eight members from my staff found themselves on a sudden crash course; Mr. Abbott's staff learning about the habits of the ward and my own staff learning about the screen for the admission and discharge system. This took just over a week. They then went to the wards; one person to four wards 14 hours a day and they were put in there for a period (intended initially for a period of 3 weeks). In the event that what happened was that after the first 3 days the whole thing died down. People became acclimatised very quickly, mainly I think, because of the education programme Miss Scholes has talked about and also because the screens were self-explanatory. Once they had a chance to make mistakes and had someone there to help them it was very easy from then on. Although it was intended to put this team in for initially three weeks, we decided eventually to withdraw them after 9 days and from then on all that was needed was some judicious follow-up of the two or three areas, (no more than that) where people were obviously having difficulty or where there were particular individuals who had great difficulty in unlearning their old habits and adjusting to the new ones.

I think in some ways it was rather like overkill but it certainly paid off in that some of the people who were then most resistant can now be seen using the system fluently, talking about it eagerly and referring to it as "mine". There were two points also that came out of this. It is very important after implementation in the first flush of success to make sure in fact that the individual users do maintain standards and there is no fall off. I think it is a behavioural thing which occurs in most other educational situations. I have already referred this morning to one or two areas in which we have not been able to maintain it and we are having to devise some longer term means of doing so.

Another point which is perhaps of particular relevance to those who are running systems and that is, that the computer staff themselves have to go through a difficult patch. We had asked for an unreasonable amount of effort on their part. We had been unreasonable about deadlines, unhelpful about holidays and so on. They got the system up and they got it up on time. When it was up, what we had not bargained for was their own feeling of 'so what'. There was a long slog ahead of them. The system was up but there was a whole lot of other things to be attached to it. A lot of other things which need night working and so on. I think next time we will probably be more receptive to the personnel needs of the experts. They are as prone to problems as are the users. One final point I think worth recording, is the excitement of quite junior staff when they found themselves handling live data and realised that it was going right across the hospital. This is really worth it.

C. USER RESPONSE

As you have heard, the administrative system has been live since about March 1973 for 14 hours a day and 7 days a week. We have not yet made a formal survey of user opinion as it has always been our intention to wait until the complete laboratory system was live before doing this, so, what I have to say will be purely anecdotal and furthermore it will be to a large extent a bringing together of the variou snippets of user comment which we get during the course of the day.

Firstly, the most striking feature of the user response is lack of comment. Knowing what human nature is and what it thinks about computers, this, it seems to us, must mean that the users accept the intrusion of this major system into the wards and offices and it must be doing more good than harm.

This then is the response of the'great silent majority'. On the more articulate side, we have heard all sorts of comments, and I propose to give a few examples. Firstly, that it is a useful facility to see on the ward VDUs what patients are coming in for each of the next seven days hence and to see what tests have to be ordered for these patients so that they can be set up in advance, thereby saving time in hospital waiting for say, an angiogram. It is also very useful to be able to review the waiting list from the ward with one's whole staff around to discuss it. Journeys to the previously crowded admission office are now much less frequently necessary. The ability to be able to review the current bed state of the hospital saves a lot of walking around and telephoning by the administrative staff. There is an enormous largely unpredicted benefit in the ability to locate where a patient is in the hospital system, i.e. whether he is still on the waiting list or on the wards or whether he has just been discharged. Now as for the ease of use of the terminals and tree branching system there is no doubt whatsoever about this. All varieties of staff including doctors, nurses, ward clerks and administrative officers have taken to it rapidly, and they require very little instruction over and above the initial introduction. Some remarkable degrees of expertise have been built up amongst the greatest sceptics. One substantial criticism was made by a firm whose method of indicating urgency was not readily compatible with that employed by the computer system, but modifications readily produced an acceptable solution. There is of course the usual quota of input errors which happened before the computer system, went live and which are now inevitably attributed to the computer. As I implied at the outset, if you really want to have a proper review of the user/response attitude you will have to wait a year or so until we have done the appropriate studies.

I must now turn to the matter of breakdowns and fall back procedures. Mr. Abbott has already touched on breakdowns briefly from the hardware point of view and I am going to say a little more about this now and also refer to what breakdowns and fall back look like to the users. Since we went live there have been two major hardware breakdowns. One of these was in the Fastrand which is the large capacity slow access drum. This was down for a total of 29 hours; this was spread, fortunately over a week-end when the normal enquiry rate is rather low, and backlog was entered during the 'ups' which occurred between the 'downs' so really people did not notice too much that anything untoward was going on. The second major breakdown was in the communications terminal module controller. This is the central telephone exchange to which all the connections from the VDUs and multiplexors all go into before they go into the computer; this is a critical point in the whole system and it is not duplexed. This was in fact 'down' for 12 hours, again, fortunately, this was overnight so again people did not notice, except that the system was a little late in coming up the next morning. Now with regard to VDU breakdowns, there are 57 VDUs around and a VDU breakdown occurs on the average about once a day somewhere in the hospital. These breakdowns have all, in fact, been dealt with on site within a half an hour and seldom, if ever, have we had to substitute that VDU by a spare one. For fall back here, the users go to the adjacent ward. The communication system is so arranged that virtually everything that can be obtained on the VDU in ward A can also be obtained in its adjacent ward, Ward B. The wards are twinned in that way so they provide a natural fall back. Furthermore the VDU in adjacent wards are attached to different multiplexors so that failure of a multiplexor does not stop one using the VDU in the twinned ward. Mr. Abbott has indicated the system is partly duplexed by the second machine and there are switching arrangements; thus the fast drums, the tape decks, the printers, the card readers are duplicated and so is the core but only at 48K instead of 80K. Thus, a variety of hardware faults can be covered. We shall shortly be able to use the second central processor for a fall back machine but seeing that it has only 48K of store response time as seen to the user will be considerably degraded. There is a further safeguard in that all transactions as they are written onto the Fastrand are also journalised on tape from which they can be recovered.

With regard to software 'bugs' there were several crashes a day in the first weeks of going live but these rapidly decayed to practically zero. Many such 'bugs' are in fact now trapped by the system so that all the user sees is after he has made a perfectly reasonable choice on the VDU frame,a notice is displayed up saying 'Sorry System-error, please start again'. At the next attempt the particular configuration of events in the computer will be slightly different and the transaction will go through normally.

Fall back procedures on the waiting list, admissions and discharges system basically consist of waiting for the system to come up again and then entering from forms the transactions that have occurred during the 'down' period. Calling patients from the waiting list during a crash is done by manual typing from a print out of the waiting list of which an updated version is provided at regular intervals just for this fall back purpose. When the clinical laboratory system comes live, fall back will consist of the use of these special manual fall back forms to which I have previously referred if the requesting system fails. If the reporting system fails these request forms are suitable for reporting on as well and when the system comes live again all requests and reports generated in the interval of the crash will be entered in. One of the troubles about fall back systems is that no one has much practice in how to use them; thus, even if you have got a pretty good fall back system one might find that great confusion and chaos is caused by the fact that people who have got to use it do not know how to. We do not think that this will be a great problem, since the fall back forms are in any case now being used for making requests from out-patients and other hospitals; the laboratory and the clinical staff will, therefore, be familiar with them.

THE APPROACH TO EVALUATION

1. Introduction

The major problem with computer project evaluation is that two new elements are introduced to the Health Service simultaneously. Firstly, the computer systems themselves are being introduced and secondly an attempt is being made at the evaluation of health care. The prime query about The London Hospital system is, does it work? Have we solved the basic problem of medical computing i.e. that of data capture and retrieval in the very difficult, multi-disciplinary ward environment?. This is definitely a non-trivial question as is demonstrated by failures both within the Health Service and elsewhere. To be successful, projects must be thought useful; "What do the users want"? is a question that is just as important as "what is the most cost-effective technical solution"?.

In the United Kingdom there has so far been very little attempt to evaluate the implications of major new Health Care programmes and thus much effort is necessary to develop appropriate and acceptable techniques. It is this lack of effort that now makes it difficult to plunge immediately into an effective computer project evaluation scheme. Steps are slowly being taken to move in this direction but they have not yet borne much fruit - it is hoped that efforts at computer project evaluation will help the development of a more critical approach to the provision of Health Care.

2. Organisation of the Evaluation

At the London Hospital the evaluation team was grafted on to the existing Operational Research Unit in the same way that the real-time project was grafted on the existing Computer Unit. In both cases this has led to a major change of emphasis in the Units but each has functions and responsibilities quite separate from the Real-Time project and its evaluation. Furthermore, each unit has long standing links within the hospital which have been immensely valuable in carrying out their activities. The Evaluation staff are, of course, independent of the computer staff even though they share the same building and work with them. The formal link occurs when their evaluation reports are presented to the Computer Executive, which is responsible for overall policy.

3. Project Objectives

The overall objective of The London Hospital's Computer Project is the long term maintenance and, if possible, the improvement of the present standard of patient care and services, despite the increasing demand for specialised forms of medical care, and the decreasing availability of staff. It is intended to achieve this objective by setting up the basis of an advanced data collection and communication system throughout the Hospital, and eventually throughout the Group. This system will monitor the functioning of the organisation, the progress of patients though their period of care, and the use of health care resources. It will, thus, provide the basic data required to achieve progressive improvements in the day to day management of the Hospital. The system will be specifically designed to relieve professional staff of routine clerical tasks.

4. Anticipated Benefits

As the computer system is designed and installed, various types of benefit will be obtained. The investigations and reports of the system and evaluation teams are already providing valuable documentation of various procedures. These studies frequently lead to simplification and improvement, quite apart from the aspects to be handled by the computer. The education programme is broadly-based and of value in relation to the use of the Hospital's batch processing computer facilities for management and research, quite apart from the real-time project itself.

The most obvious product of the system will be the implementated real-time computer system itself, and most of the evaluation proposals relate directly to this system. The system will additionally make it possible to monitor and isolate problem areas in the operation of the Hospital and ultimately lead to improved management of these areas. One of the basic concepts underlying the introduction of the system is the idea that the provision of relevant data on the performance of various aspects of the Hospital will lead to improvements in performance. Staff will find themselves able to utilise this information to expedite the investigation and treatment of their patients by better scheduling. In addition, the system will enable the response of service departments to be more effective. It is anticipated that ultimately there will be changes in the administrative delays to the patient's progress through the Hospital and in the pattern of activity of the medical and nursing staff. These changes will depend on medical, nursing or administrative decisions on how the potential provided by the system should be exploited.

For example, the time between a clinical laboratory request and the time the result appears on the ward (transit time) is a crude measure of theoperation of the laboratories. The computer system will remove the delay in communication after the result has been obtained, will reduce the chance of a request being overlooked when a specimen cannot be obtained and will help to avoid the repetition of requests which frequently occurs when the transit time is lengthy. If further work indicates that there are sufficient advantages to be gained, it is clear that attention must be paid to the specimen collection procedure and to the basic laboratory organisation - e.g. the batching of tests. Since the transit times are measured automatically by type of test, they can be used by the Director of the Laboratories as a measure of performance, particularly during periods of re-organisation.

5. Some of the major problems encountered

The evaluation of any major project gives rise to a number of problems. The more important ones are the following:-

(a) The Nature of Health Care

The lack of agreed measures of health care makes it difficult to place a value on organisational improvement except when a small self-contained section of the health care system is tackled. This longstanding lack of effort at the evaluation of health care programme means that new techniques have to be devised and validated during the attempt at computer project evaluation. Itmay be that one of the most important contributions of the experimental computer program to the National Health Service will be the initiation of the concepts of program evaluation.

(b) The Nature of the Information

The information sought is often of a highly confidential nature sometimes it can be potentially damaging to individual stafff if it is wrongly used. A great deal of trust has to be built up before any staff are allowed to accumulate such information.

(c) Access to Information

Much of the information is not available currently, has never been collected or even thought worth collecting. It certainly is not available as of right nor can it be demanded. It requires the active and willing co-operation of many hospital staff. This sort of collaboration is built up over the years, and it is necessary to prove to the staff that you are aware of their problems and are willing to help

(d) The Nature of the Work

The attempt at evaluation ranges from data collection, through work study techniques and computer science to operational research, accountancy and economics. This range from trivial data collection work to sophisticated modelling can cause some complications in staff selection. The fact that the evaluation is based on an operational research group means that staff can be kept interested with an appropriate mix of activities. Computer Evaluation by itself could rapidly become sterile unless some other outlet is forged - e.g. to general Health Care Evaluation.

6. The Development of Application Evaluation

Suggestions about evaluation were included by the Computer Executive in their Feasibility Study. These were amplified into proposals for detailed projects by the Director of Operational Research on the general basis of carrying out 'before' and 'after' measurements in a number of relevant areas. It was recognised that, for a project lasting many years, it would be difficult to ascribe some changes to the computer project but yet it was none less vital to have accurate measurements for reference purposes. These suggestions were accepted by D.H.S.S. and have with minor exceptions been carried out. Thus the evaluation was firmly set as a 'project evaluation'.

However, during the first phase of the development of The London Hospital Computer Project, the Department of Health carried out their review of the experimental program and developed the current policy of supporting an application evaluation approach. It was therefore necessary to attempt to restructure from 'project' evaluation to 'application' evaluation. Logically, the approach utilising controlled statistical trials provide a theoretical basis for application evaluation but at the present stage of development there are a number of difficulties in using this approach:-

(a) there is no more than supeficial similarity between the same applications handled by different projects.

(b) the applications are not independent.

(c) there is no clear numerical measure of success common to either applications or projects.

(d) the number of projects and applications are currently so sparse that no real statistical examination of the interacting effects of project, application and performance is yet possible.

Nevertheless, this sharpening up of the program of evaluation is to be welcomed but this approach has so far only led to a multiplicity of 'improvement objectives' and 'measure of performance' being listed and measured (v. 1973 analysis of AR3).

The items listed vary from important objectives to various odd side effects that might or might not occur, and almost everything is thought to affect key parameters such as discharges per available bed.

It must be clearly understood that evaluation is not a single item but a multiplicity of 'evaluations'. These are needed for specific purposes. They must be related to these purposes and to the decision making structure as closely as possible. A few examples of this are listed below:-

I Individual Project Evaluation

This attempts to throw light (retrospectively) on the decision process.

(a) Should the project have been funded-given the information and results obtained (both positive and negative)?

(b) Was the right hardware purchases?;

(c) Has the project improved the functioning of the service?.

II Application Evaluation

This attempts to structure information obtained by projects into the 'Experiment - Development - Implement' format in order to decide which applications should be developed and implemented The evaluation must be sharply focussed to what is needed for this decision making. Hence, the clearer the D.H.S.S. can specify its decision rules and mechanisms, the more relevant the evaluation can be its decision processes.

III Technique Evaluation

This attempts to examine the hardware and software combination employed by the projects and to assess an optimum mix of equipment to cover the computing and information need of the future Districts, Areas, Regions and country. For example, in the context of The London Hospital is a Univac 418/III the best way of making the system available throughout the District or would this objective be handled better for instance by a group of smaller machines or as part of a larger system at Area or Regional level. At present this aspect of evaluation is largely being ignored.

The main difficulty with regards to objectives is that D.H.S.S. does not yet appear to have functioning objectives for the Health Service corresponding to the improvement objectives of the projects - although this may be coming with Rothschild Customer - Contractor approach to research. When these overall objectives are developed it will be vital to examine which areas are most appropriate to computer approaches rather than equipment, medical advance or even good organisation.

7. Format of the Evaluation

The main part of the Evaluation will be the attempt to balance application benefits with implemented application costs. However, there will be a number of component parts of the total evaluation which together build up to this final balance - as follows:-

(a) Description of Hospital

Although there will be immediate benefits from the system, the full effects will take a decade or so to develop. Hence the first task of the evaluation must be to produce a reference framework against which the Hospital's activities can be repeatedly measured during such a period. The extreme difficulties of data collection without an operational real-time system have led to the view that this framework should comprise a variety of measurements of different aspects of the Hospital's performance using relatively small samples, rather than relying on one or two measures collected in sufficient quantities to guarantee that small changes can be detected at a high level of statistical confidence. This framework includes the detailed measurements required for the analysis of specific immediate changes. As has been mentioned the basic difficulty is that there is no generally accepted means of measuring the performance of a hospital or of meaasuring the quality of medical care.

The evaluation reports have been prepared as each section of the work is completed. The final document will be compiled, using these reports as appendices. This approach allows the picture to build up over a period of time with the information becoming available at the earliest opportunity.

(b) Description of Computer System Installed

(i) Technical Characteristics

This description will include a technical assessment of the characteristics of the system. First and foremost, does the system solve the basic problem of medical computing; that of providing acceptable and convenient data entry and inspection? Do the parts of the system work as planned? Does the system work as a whole? Does the tree branching approach to data entry and inspection function satisfactorily? What is the capacity of the system for expansion? How reliable has the equipment proved in practice?

(ii) Information Available Routinely

The information available from the system will be listed together with the summarised information used for the management and control of hospital procedures.

(iii) User Acceptance

This section will indicate the degree of user acceptance of the system. How much is the system used and by whom? How well does it meet user's needs? How convenient is it and how efficient is it?

(c) <u>Immediate Effects</u>

There will be immediate effects from the installation of certain parts of the system and direct comparisons can be made with previous measurements. For instance, the Clinical Laboratory system will provide quality control facilities for the laboratories, more complete information in the request forms, a check on specimen collection failures and a faster return of results. The admission-discharge system will provide more sensitive control of use of beds, and more accurate patient administrative information. Measurements will be made in these and similar quite specific areas of the direct effects of the system. Staffing changes will be noted and the effects of the system will be compared with the intentions of the system designs.

(d) <u>Long Term Effects</u>

Measurements will be made at intervals in order to detect changes in the pattern of use of the Hospital's resources, of administrative delays to the patients' progress and of staff activity. Changes will be noted in comparison with the original reference framework but in many cases the chain of events will probably be so complex that no direct casual relationship can be claimed. Nevertheless, the details of these long term changes will be of considerable interest and significance.

(e) <u>Application Benefits</u>

From the foregoing studies it should be possible to assign application benefits. The major problem will be separating the benefits occurring from individual small applications. It is likely that the application package will have to consist of the waiting list, admission/discharge and the clinical laboratory system as a whole, because the systems themselves and their benefits are so interdependent.

(f) Application Costs.

These costs relate to the cost of development and implementation elsewhere in the National Health Service rather than the sunk costs of The London Hospital project. These estimates will use standard D.H.S.S. accounting conventions and the main cost components will be:-

1. The hardware costs amortised over seven years
2. Annual Hardware Maintenance
3. Annual Software Maintenance
4. Annual Operations Costs
5. Consumables and Supplies
6. Building Cost amortised over 20 years

These figures will generate a total annual system cost for the facilities. The individual applications cost will be allocated on the basis of the proportion of the facilities utilised to implement the application. A simulation study, described later, is being carried out to assist with this allocation problem.

8. An outline of the Results from Some of the Major Studies

(a) Transit Times for Clinical Laboratory Requests

A series of studies were undertaken to examine the time between the request for one of the tests processed daily in the Biochemistry and Heamatology Laboratories and the availability of the result on the ward. Initially this was carried out by the laborious process of using time and date stamps but subsequently a model was devised based on dates alone. FIGURE 1 and 2 show the time distribution for these two laboratories. The mean transit times are 2.27 and 1.32 days respectively. The composition of the total transit was studied by examining the collection delays, testing times and the transmission delays. It was found that combinations of exponential distributions could be fitted to these times as shown in FIGURE 3. The whole situation could be described by a markov chain model indicated in FIGURE 4.

Having validated this model it is possible to examine the effect of:

(a) delivering forms to the wards on the day they are signed.

(b) collecting specimens on the same day as the request.

(c) reducing certain long delays in testing.

(d) combining prompt specimen collection and report delivery.

The predicted changes in transit times from the model are shown in FIGURE 5.

(b) Simulation of the Clinical Laboratory Office

The workload in the laboratories has been climbing steadily and it was clear that it would be necessary to compare the benefit of the computer system not with the hospital situation before implementation but with that which would have arisen from the current workload had it been handled by the previous manual systems. Detailed studies were carried out in the clinical laboratory office in order to simulate the handling of the work-load and the delays imposed on the transmission of results by the system. With the aid of this model it is possible to predict the staffing and equipment to provide given levels of service. FIGURE 6 gives an illustration of the results available indicating the resources required for a specified level of service at different workloads.

(c) Completeness of Clinical Laboratory Requests.

FIGURE 7 shows the outline of an analysis of 6592 request forms. Nearly 45% of forms were incomplete in some fashion and the total incompleteness was 7.8%. The medical advisory committee then provided scores of the importance of the various items. These were averaged and then used to deduce a mean weighted incompleteness figure of 7.5%.

(d) Probability of Blood Collection

FIGURE 8 shows the results of 23 days study of the phlebotomists rounds. The latter failed to collect blood specimen in 10.6% of attempts for the reasons indicated.

(e) Ward Staff Activity

Activity sampling was carried out in four wards to ascertain the pattern of nursing activity. This material was analysed by type of staff, by rota and by detailed activity. The nursing activity averaged as:-

Activity	Percentage
direct patient care	39.2 ± 2.2
indirect patient care	10.9 ± 2.6
administration	7.69 ± 2.0
routine/household	5.01 ± 2.7
reporting	10.66 ± 2.6
rest	21.7 ± 2.4
absence	4.95 ± 2.1

quoting the 95% confidence intervals.

This study gave some useful information about ward clerk activity and this was used as the basis for a detailed study on all ward clerks. An appropriate list of activities was devised and the following results were obtained:-

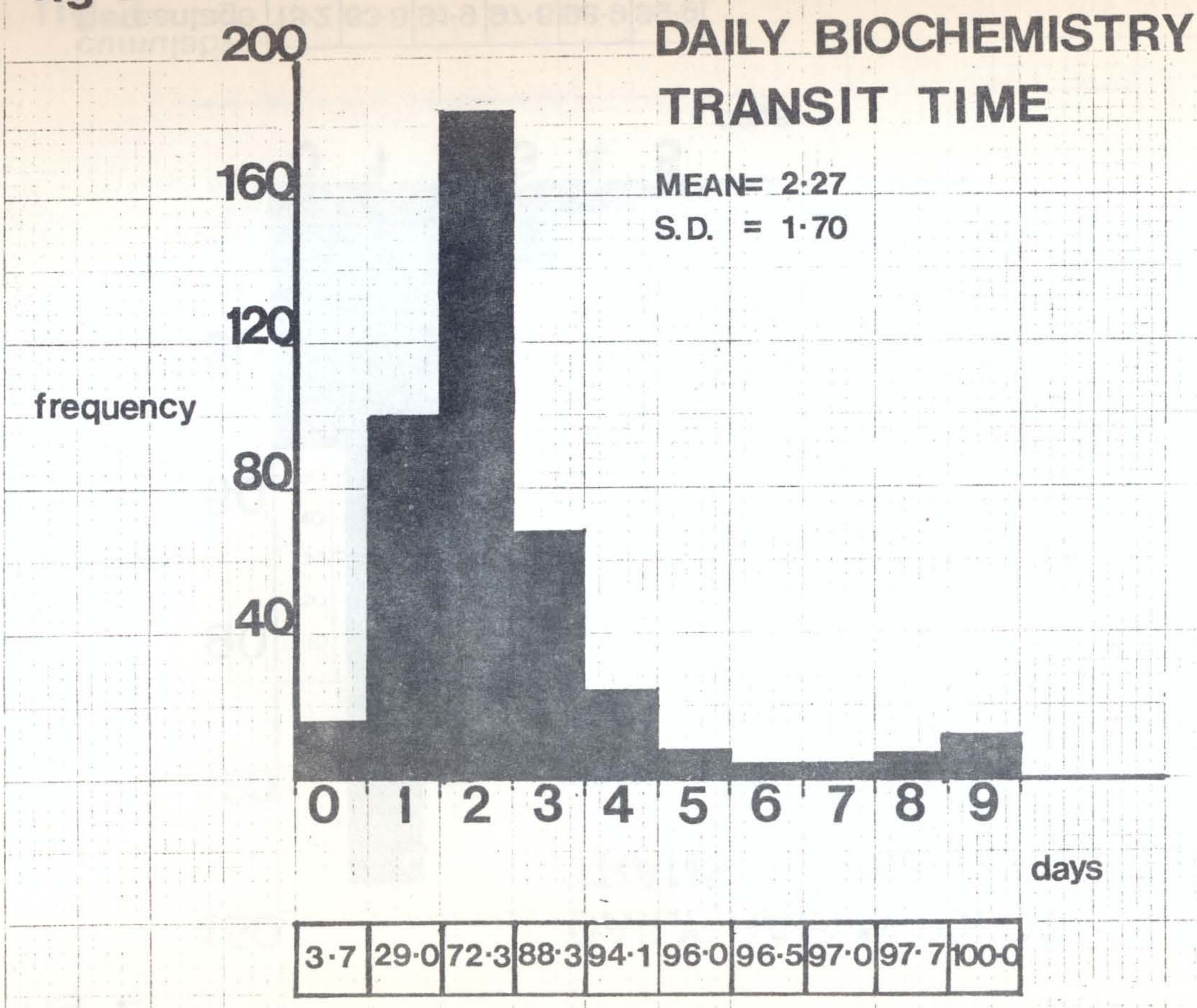
Activity	Percentage
Direct patient care	4.8 ± 6.2
indirect patient care	5.5 ± 6.1
administration	68.0 ± 3.6
receiving instructions	2.7 ± 6.2
rest/meal breaks	19.0 ± 5.7

When this is related to the computer system activities the results are:-

Activity	Percentage
Clinical Laboratory	5.6 ± 1.5
Waiting List & Admission Discharge	29.4 ± 2.9
administration	33.1 ± 3.0
Other activities	32.0 ± 2.9

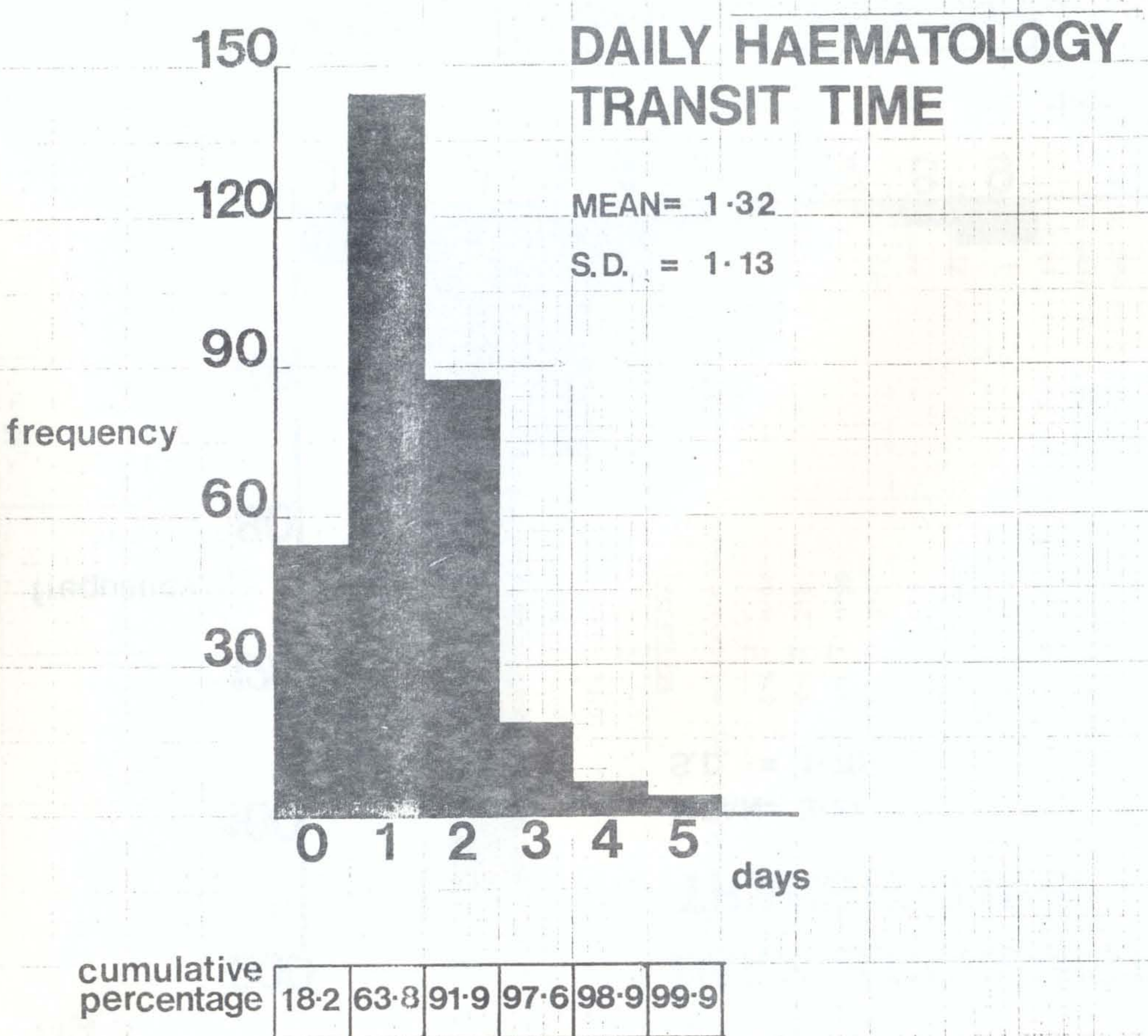
One of the most difficult aspects of the study was the elucidation of activities carried out away from the ward.

fig 1



DAILY BIOCHEMISTRY
TRANSIT TIME
MEAN= 2·27
S.D. = 1·70
200
160
120
80
40
frequency
0
1
2
3
4
5
6
7
8
9
days
3·7
29·0
72·3
88·3
94·1
96·0
96·5
97·0
97·7
100·0

fig 2


DAILY HAEMATOLOGY
TRANSIT TIME
MEAN= 1·32
S.D. = 1·13
150
120
90
60
30
frequency
0 1 2 3 4 5
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63·8
91·9
97·6
98·9
99·9

fig 3

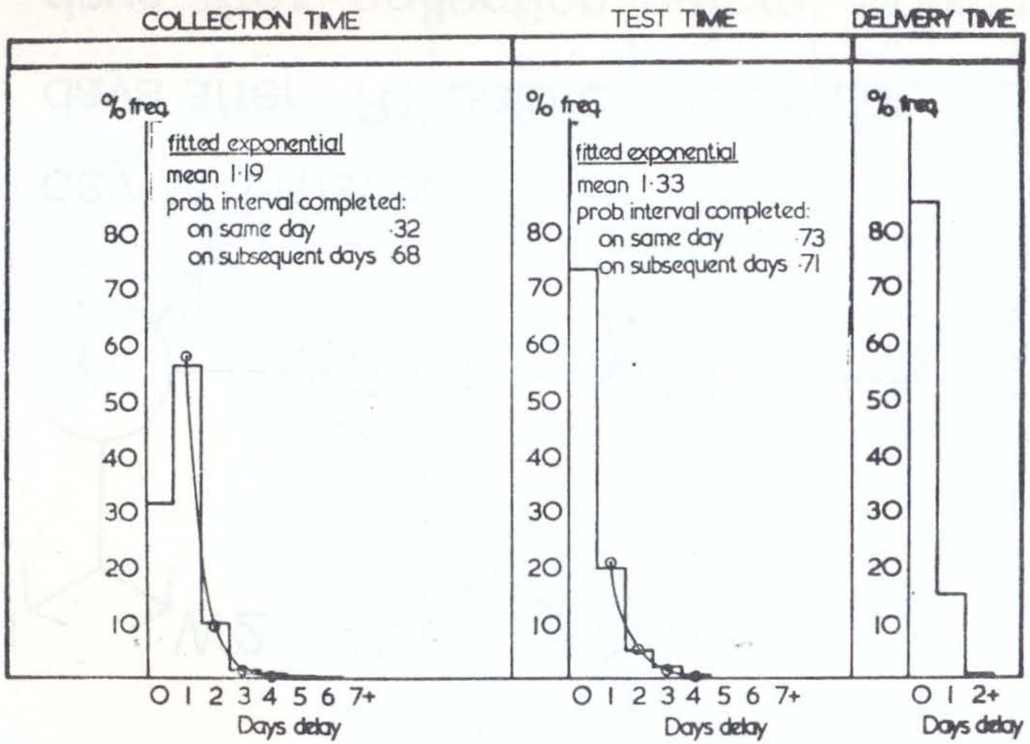
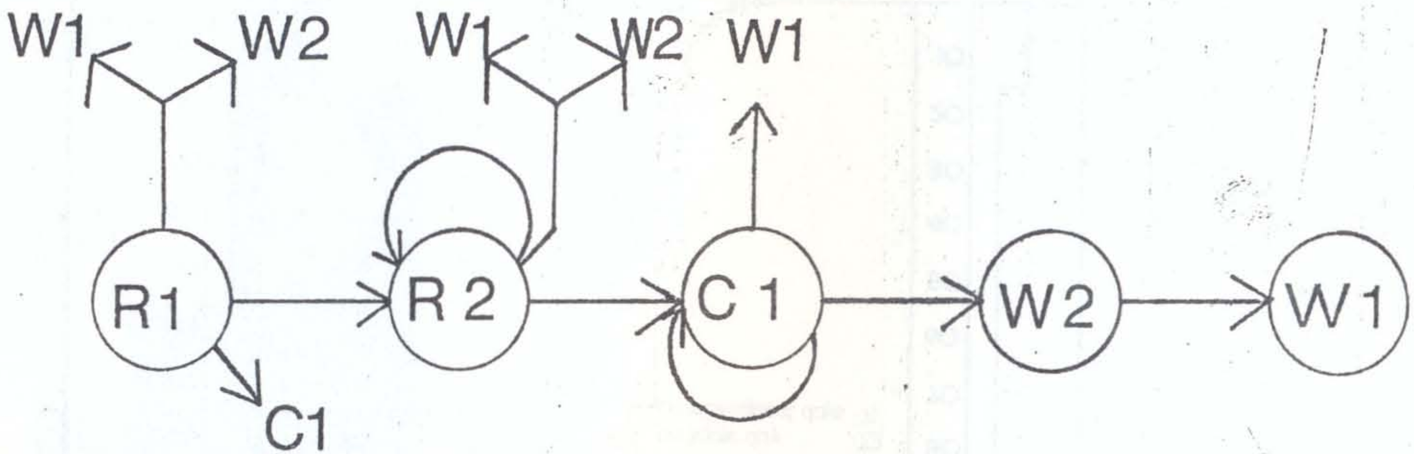

COLLECTION TIME
TEST TIME
DELIVERY TIME
% freq
fitted exponential
mean 1·19
prob. interval completed:
on same day ·32
on subsequent days ·68
% freq
fitted exponential
mean 1·33
prob. interval completed:
on same day ·73
on subsequent days ·71
% freq
80
70
60
50
40
30
20
10
0 1 2 3 4 5 6 7+
Days delay
0 1 2 3 4 5 6 7+
Days delay
0 1 2+
Days delay

FIGURE 4

MARKOV CHAIN MODEL TRANSIT TIMES



R1: day of initiation

R2: days after R1 before collection

C1: days after collection before signing

W1: reports arriving same day as signed

W2: reports arriving day after signing

FIGURE 5

SUMMARY OF EXPERIMENTATION

Mean Transit Times (Days)

	Daily Biochemistry	Non-Daily Biochemistry	Daily Haematology	Microbiology
Observed	2.27	4.47	1.32	3.13
Simulated	2.26	4.34	1.28	3.02
Experiment 1 (Reduced posting delay)	1.74	4.11	1.12	2.95
Experiment 2 (Reduced sample collection delay)	1.72	4.13	1.08	2.14
Experiment 3 (Reduced testing Time)	2.18	3.06	1.30	2.66
Experiment 4 (Exp. 1 and Exp 2 combined)	1.49	3.70	1.03	2.07

FIGURE 6

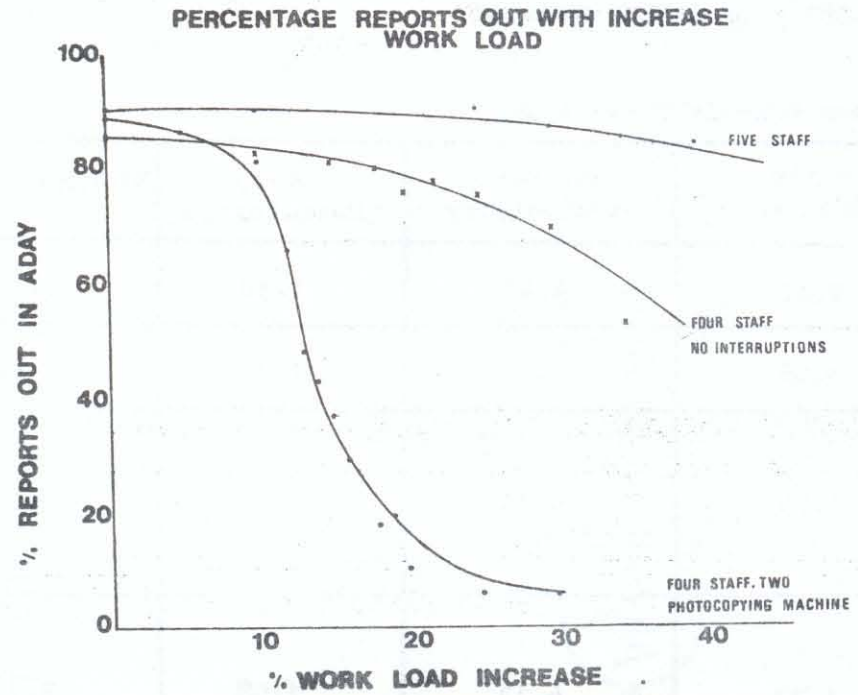


FIGURE 7

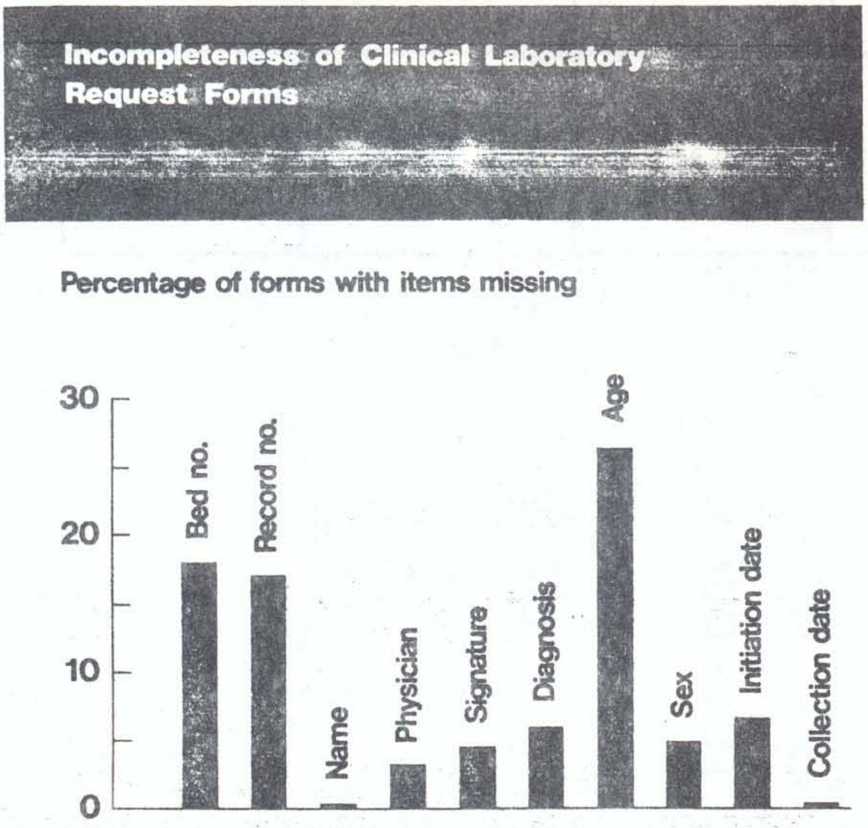
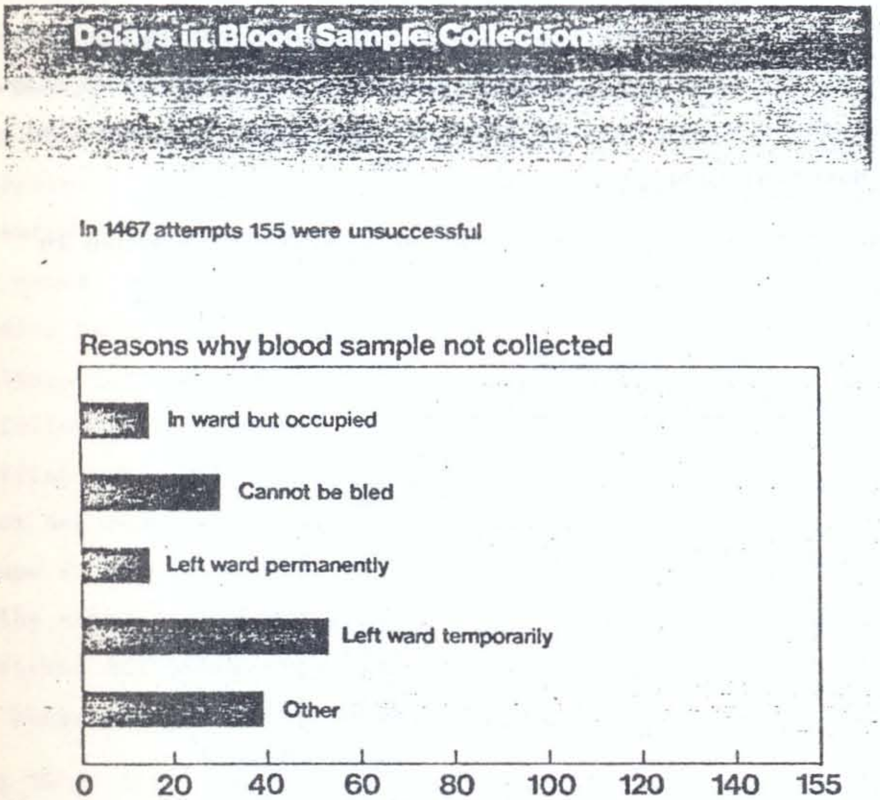


FIGURE 8


Delays in Blood Sample Collection
In 1467 attempts 155 were unsuccessful
Reasons why blood sample not collected
In ward but occupied
Cannot be bled
Left ward permanently
Left ward temporarily
Other
0
20
40
60
80
100
120
140
155

(f) Analysis of Hospital Performance

In order to present data on the functioning of the hospital which are not influenced by the changes in case-mix, it was suggested that parameters such as length of stay, turnover interval, discharges per available bed and percentage bed occupancy should be related to a standard case-mix of 'core' specialities selected from the national case-mix. The chosen specialities account for 71% of the national discharges (using 1971 figures). They are general medicine, paediatrics, general surgery, E.N.T. Traumatic andOrthopaedic surgery, gynaecology and obstetrics.

Over four thousand sets of patients case notes were examined on discharge to analyse the use of the hospitals resources during the in-patient stay. This has been analysed by diagnosis, of medical speciality and hospital within The London Hospital Group.

An abstract of some of this material for core specialities is shown in FIGURE 9 (Tables 1 - 3).

FIGURE 9

Average Number of Requests Per Patient Discharge

	Biochemistry Laboratory
General Medicine	5.50 (83.6%)
Paediatrics	0.85 (24.4%)
General Surgery	1.57 (45.5%)
E.N.T.	0.92 (21.0%)
Orthopaedics	0.89 (32.6%)
Gynaecology	0.63 (21.2%)
Obstetrics	0.58 (16.2%)
TOTALS	2.33 (48.9%)

(g) The Quality of Patient Notes and Hospital Activity Analysis Returns

As part of the resource study about 5% of the case notes examined were checked by non-medical staff for coding errors, completeness, misfiling. FIGURE 10 gives an outline of some of the more obvious problems encountered.

(h) Patient States

A considerable amount of effort was expanded over a number of years in trying to get some estimates of the delays to the patients progress through his in-patient stay. The final method adopted involved the house officers categorising their patients delay as awaiting results, decisions, treatment or discharge. Alternatively, the patients were recorded as under observation, having treatment or having terminal care. The surveys were carried out monthly on different days of the week and were analysed by medical speciality. The major results are shown in FIGURE 11 showing a total of 45.3% of patients were recorded as awaiting some form of activity. In general medicine the figure for patients awaiting results rose to 23.4% while in general surgery the figure for patients awaiting treatment was 18.8%.

(i) Attitude Surveys

An essential element of the evaluation relates to the measurement of behavioural variables. These measures concern the broad sweep of the hospital's problems, possible solutions to them and attitudes to computers. The survey was carried out using a structured interview technique for completing a questionnaire. The latter was devised following unstructured interviews utilising appropriate hospital phraseology and tested by repeated pilot trials

The questions are designed to complement the information gathered in other studies by examining staff perception of their situation. The statistical analysis was related to groups of questions covering one general area as follows:- admissions office, emergency and accident department, beds, staffing, theatres, clinical laboratory tests, discharge, after care, case index and computers. With the observations obtained from the various staff groups it should be possible to detect a mean shift of attitude of 0.5 in the sample using a standard 5 point response scale for most groups of questions and staff. The total survey gives a strikingly clear picture of the hospital view of its problems and how they might be alleviated.

Only 3% of the staff interviewed considered the computer project plans 'generally bad'. The majority considered them 'generally good' or were undecided and thus willing to judge the system by its results.

(j) Simulation Model of Computer System

The basic limitation in the computer system is its ability to handle requests expeditiously. If the system response becomes sufficiently long, staff will find some way to avoid using the system and it will cease to be an effective real-time system. The computer system is an exceedingly complex hardware and software configuration. However, it is assuming that it is in some sense a 'balanced' configuration and that the key aspects of the system are concerned with the handling of the communications then the model can give estimates of the spare capacity of the system.

Estimates will be made of the acceptable response times and hence applications can be allocated an appropriate proportion of the system costs. This model still requires further testing but at present it appears to be adequate.

9. Conclusion

This necessarily brief review only indicates a few of the more interesting results from the 'before' study. There is much that would repay detailed study in the wide range of problems examined and much that suggest guidelines for action to improve the system. The major evaluation study will be carried out after the clinical laboratory systems have gone live. However, FIGURES 12 & 13 indicate the substantial amount of system activity throughout the period when the system is operational. From the very limited scope of the present system and the ratio of system inspection to updating transactions it is indicative of quite widespread acceptance and usage. In this sense, and in advance of the detailed evaluation, the system has successfully coped with the problem of ward data capture and retrieval. It works, it is used and it is useful.

FIGURE 14 compares the manual and computer systems for handling the wait list. It shows the extra completeness of the computer system.

TABLE 1. LONDON HOSPITAL.

Average Resource Utilisation of all Discharges	Haematology Tests	Biochemistry Tests	Bacteriology Tests	Blood Group Tests	X-Ray Chest	X-Ray Plain	X-Ray Special	Pathology	Ear Tests	Radiotherapy	Theatres (Hours)	Theatres (Unknown)	I.T.U. (Hours)	Dialysis - Hours	E.C.G.	E.C.T.	E.E.G.	E.M.G.	Pulmonary Function Tests	Radio Iodine	Eye Tests	Brain Scan	Scans (Other)	Intelligent Tests	Physiotherapy	Occupational Therapy	Bone Scan	Sample Size	Length of Stay
GENERAL MEDICINE	3.32	5.50	2.82	0.32	1.11	0.59	0.38	0.38		0.08	0.11	0.18	0.60	0.29	0.89		0.08	0.01	0.04	0.03	0.04	0.05			0.06			476	15.0
PAEDIATRICS	1.01	0.85	1.83	0.11	0.26	0.16	0.08	0.02			0.02	0.16			0.16		0.05		0.01			0.04			0.02			86	12.0
CHEST DISEASES	3.39	3.72	8.78	0.17	2.17	0.39	0.11	0.72		0.17	0.11	0.06	0.83		0.39				0.22						0.22			18	30.3
DERMATOLOGY	2.17	3.89	8.78	0.17	0.72	0.33	0.17	0.22			0.01	0.11			0.33			0.06	0.11						0.33			18	26.6
CARDIOLOGY	5.98	9.10	3.85	0.56	2.51	0.14	0.20	0.16			0.26	0.31	10.44		3.35		0.21		0.08	0.01			0.14	0.00	0.02	0.01		94	20.2
PHYSICAL MEDICINE	1.84	3.04	2.84	0.28	0.56	2.32	0.12	0.16	0.04		0.15	0.28			0.44			0.04										25	16.2
V.D.	3.63	2.63	3.13	0.13	1.00		0.13	0.13				0.13			0.25										0.25			8	21.8
GERIATRICS	2.00	5.00	1.00		2.00	1.00																			1.00			1	33.0
GENERAL SURGERY	1.42	1.57	0.97	0.56	0.43	0.32	0.16	0.50		0.06	0.41	0.49	0.60		0.18				0.01	0.01					0.02			561	11.5
E.N.T (T/A)	0.66	0.14	0.21	0.14	0.31	0.31	0.10	0.52		0.14	0.34	0.83			0.07		0.03		0.03			0.10						29	9.8
E.N.T (OTHER)	0.83	1.09	0.55	0.11	0.34	0.17	0.06	0.38	0.04	0.04	0.65	0.43			0.23						0.02	0.04						53	9.5
ORTHOPAEDIC	1.55	0.89	0.85	0.57	0.14	0.31	0.02	0.10		0.04	0.37	0.57	0.68		0.16	0.01			0.01						0.01		0.01	193	18.5
OPTHALMIC	0.27	0.46	0.23		0.09						0.22	0.27			0.05													22	14.6
RADIOTHERAPY	2.59	1.40	1.62	0.15	0.68	0.62	0.21	0.45		1.76	0.09	0.43			0.15							0.06	0.02				0.02	53	17.6
UROLOGY	1.73	2.70	5.27	0.62	0.44	0.18	0.26	0.47		0.21	0.69	0.62	0.12	2.70	0.13								0.01		0.03			117	14.0
PLASTIC SURGERY	1.04	0.12	0.89	0.77	0.27	0.23		0.23			0.04	1.00					0.04											26	12.3
THORACIC SURGERY	2.41	2.79	4.38	1.32	0.39	0.44	0.16	1.78	0.01	0.24	0.51	0.71	0.11	0.78	0.88				0.24						0.01			107	14.8
DENTISTRY	0.49	0.05	0.26	0.04	0.05	0.02		0.04			0.33	0.58	0.35		0.02													57	4.9
NEUROSURGERY	1.69	1.49	1.61	0.19	0.27	0.63	0.67	0.21		0.18	0.75	0.46	0.76		0.10		0.08					0.06			0.08			67	15.1
GYNAECOLOGY	1.54	0.63	2.06	0.25	0.13	0.07	0.04	0.57			0.22	0.70			0.05										0.04			339	11.4
OBSTETRICS	2.00	0.58	1.46	0.38	0.08	0.07		0.38		0.01	0.13	0.76			0.04										0.01			272	12.4
PSYCHIATRY CHILDREN	0.75	0.50	0.38		0.38		0.13									1.25	0.50					0.33		0.63				8	95.3
NEUROLOGY	1.58	3.48	1.54	0.24	0.71	0.74	0.43	0.24		0.23	0.19	0.30			0.31		0.29	0.06		0.02	0.06	0.23			0.14			87	16.2
TOTAL	1.95	2.33	2.04	0.41	0.53	0.34	0.17	0.43		0.10	0.29	0.48	0.64	0.20	0.40		0.04		0.02	0.01	0.01	[illegible]2			0.04			2707	14.6

TABLE II. LONDON HOSPITAL

Average Resource Utilisation of all Discharges Using The Resource. [For %age of Discharges Using a Resource see Table III]	HAEMATOLOGY TESTS	BIOCHEMISTRY TESTS	BACTERIOLOGY TESTS	BLOOD GROUP TESTS	X-RAY CHEST	X-RAY PLAIN	X-RAY SPECIAL	PATHOLOGY	EAR TESTS	RADIOTHERAPY	THEATRES (HOURS)	THEATRES (UNKNOWN)	I.T.U. (HOURS)	DIALYSIS HOURS	E.C.G.	E.C.T.	E.E.G.	E.M.G.	PULMONARY FUNCTION TESTS	RADIO IODINE	EYE TESTS	BRAIN SCAN	SCANS (OTHER)	INTELLIGENT TESTS	PHYSIOTHERAPY	OCCUPATIONAL THERAPY	BONE SCAN
GENERAL MEDICINE	4·03	6·58	4·17	1·44	1·70	1·67	1·55	1·78		5·43	1·53	1·10	71·25	67·74	1·91		1·18	1·67	1·06	1·18	3·00	3·44	1·00	1·00	1·00	1·00	
PAEDIATRICS	2·81	3·48	4·36	1·13	1·16	1·27	1·40	1·00			1·73	1·17			1·75		1·00		1·00			3·00			1·00		
CHEST DISEASES	3·81	3·94	8·78	1·50	2·60	1·75	1·00	2·60		3·00	2·00	1·00	15·00		1·40				1·00						1·33		
DERMATOLOGY	2·44	4·67	9·29	1·00	1·00	1·20	1·00	1·33			0·24	1·00			1·20			1·00	1·00						1·20		
CARDIOLOGY	6·78	10·19	5·57	1·52	3·01	1·33	1·42	1·63			2·43	1·13	79·73		3·65		2·25		1·00	1·00			6·00		1·00	1·00	
PHYSICAL MEDICINE	2·42	4·00	4·18	1·17	1·00	3·63	1·50	1·33	1·00		1·26	1·17			1·10			1·00							1·14		
V.D.	3·63	3·00	4·17	1·00	1·33		1·00	1·00				1·00			1·00										2·00		
GERIATRICS	2·00	5·00	1·00		2·00	1·00																			1·00		
GENERAL SURGERY	2·08	3·46	2·66	1·32	1·31	1·70	1·36	1·40		3·30	1·65	1·08	47·75		1·22		2·00		1·00	1·00			1·00		1·11		
E.N.T. (T/A)	1·36	1·00	1·20	1·33	1·29	1·80	1·50	1·50		4·00	1·39	1·09			1·00		1·00		1·00			3·00					
E.N.T (OTHER)	1·63	4·83	3·63	1·50	1·39	1·50	1·00	1·54	1·00	2·00	1·71	1·00			1·20						1·00	2·00					
ORTHOPAEDIC	2·12	2·73	2·45	1·45	1·30	1·77	1·00	1·18		2·33	1·90	1·09	66·00		1·50	1·00			1·00						1·00		1·00
OPTHALMIC	1·00	3·33	1·25		1·00						0·61	1·00			1·00												
RADIOTHERAPY	3·43	2·85	2·53	1·00	1·39	1·65	1·10	2·00		8·46	1·16	1·21			1·00							3·00	1·00				1·00
UROLOGY	2·53	3·95	6·62	1·67	1·49	1·40	1·25	1·31		3·43	1·92	1·07	14·00	157·97	1·25								1·00		1·00		
PLASTIC SURGERY	1·23	1·50	2·56	1·25	1·00	2·00		1·00			1·00	1·13					1·00										
THORACIC SURGERY	2·63	3·24	5·79	1·70	1·40	1·52	1·31	2·88	1·00	2·17	1·71	1·27	12·00	41·50	1·31				1·08						1·00		
DENTISTRY	2·33	1·50	1·88	1·00	1·00	1·00		1·00			1·26	1·03	20·00		1·00												
NEUROSURGERY	2·17	2·86	3·18	1·44	1·20	2·33	1·88	1·27		12·00	2·09	1·11	25·50		1·00		1·00					2·00			1·25		
GYNAECOLOGY	1·84	2·99	3·22	1·26	1·10	1·15	1·09	1·09		1·00	1·26	1·03			1·42					1·00					1·00		
OBSTETRICS	1·58	3·57	2·81	1·27	1·10	1·13	1·00	1·16		1·00	1·03	1·01			1·10										1·00		
PSYCHIATRY CHILDREN	1·00	1·00	1·00		1·00		1·00									10·00	2·00					1·50		1·67			
NEUROLOGY	1·88	3·94	2·53	1·31	1·07	1·60	1·48	1·91		5·00	1·69	1·08			1·00		1·19	1·00		1·00	2·50	2·86			1·09		
TOTAL	2·63	4·75	3·85	1·40	1·56	1·68	1·44	1·49	1·00	4·34	1·59	1·07	58·01	89·07	1·80	5·50	1·30	1·20	1·05	1·11	2·67	2·82		1·50	1·08	1·00	1·00

TABLE III LONDON HOSPITAL

Percentage of Discharges in a Specialty Using a Resource	HAEMATOLOGY TESTS	BIOCHEMISTRY TESTS	BACTERIOLOGY TESTS	BLOOD GROUP TESTS	X-RAY CHEST	X-RAY PLAIN	X-RAY SPECIAL	PATHOLOGY	EAR TESTS	RADIOTHERAPY	THEATRES (HOURS)	THEATRES (UNKNOWN)	I.T.U. (HOURS)	DIALYSIS-HOURS	E.C.G.	E.C.T.	E.E.G.	E.M.G.	PULMONARY FUNCTION TESTS	RADIO IODINE	EYE TESTS	BRAIN SCAN	SCANS (OTHER)	INTELLIGENT TESTS	PHYSIOTHERAPY	OCCUPATIONAL THERAPY	BONE SCAN
GENERAL MEDICINE	82·4	83·6	67·6	21·8	65·3	35·5	24·6	21·4		1·5	7·4	16·4	0·8	0·4	46·6		7·1	0·6	3·8	2·3	1·3	1·5	0·4	0·2	5·9	0·2	
PAEDIATRICS	36·0	24·4	41·9	9·3	22·1	12·8	5·8	2·3			1·2	14·0			9·3		4·7		1·2			1·2			2·3		
CHEST DISEASES	88·9	94·4	100·0	11·1	83·3	22·2	11·1	27·8		5·6	5·6	5·6	5·6		27·8				22·2						16·7		
DERMATOLOGY	88·9	83·3	94·4	16·7	72·2	27·8	16·7	16·7			5·6	11·1			27·8			5·6	11·1						27·8		
CARDIOLOGY	88·1	89·3	69·0	36·9	83·3	10·7	14·3	9·5			10·7	27·4	13·1		91·7		9·5		8·3	1·2			2·4		2·4	1·2	
PHYSICAL MEDICINE	76·0	76·0	68·0	24·0	56·0	64·0	8·0	12·0	4·0		12·0	24·0			40·0			4·0							28·0		
V.D.	100·0	87·5	75·0	12·5	75·0		12·5	12·5				12·5			25·0										12·5		
GERIATRICS	100·0	100·0	100·0		100·0	100·0																			100·0		
GENERAL SURGERY	68·3	45·5	36·5	42·4	32·6	18·7	11·8	35·7		1·8	25·1	44·9	1·2		14·8		0·2		0·5	0·5			0·5		1·6		
E.N.T. (T/A)	48·3	13·8	17·2	10·3	24·1	17·2	6·9	34·5		3·4	24·1	75·9			6·9		3·4		3·4			3·4					
E.N.T. (OTHER)	50·9	22·6	15·1	7·5	24·5	11·3	5·7	24·5	3·8	1·9	37·7	43·4			18·9						1·9	1·9					
ORTHOPAEDIC	73·1	32·6	34·7	38·9	10·4	17·6	1·6	8·8		1·6	19·7	52·3	1·0		10·4	0·5			0·5				0·5		1·0		0·5
OPTHALMIC	27·3	13·6	18·2		9·1						36·4	27·3			4·5												
RADIOTHERAPY	75·5	49·1	64·2	15·1	49·1	37·7	18·9	22·6		20·8	7·5	35·8			15·1							1·9	1·9				1·9
UROLOGY	68·4	68·4	79·5	36·8	29·9	12·8	20·5	35·9		6·0	35·9	58·1	0·9	1·7	10·3								0·9		2·6		
PLASTIC SURGERY	84·6	7·7	34·6	61·5	26·9	11·5		23·1			3·8																
THORACIC SURGERY	91·6	86·0	75·7	77·6	28·0	29·0	12·2	61·7	0·9	11·2	29·9	56·1	0·9	1·9	67·3				22·4						0·9		
DENTISTRY	21·1	3·5	14·0	3·5	5·3	1·8		3·5			26·3	56·1	1·8		1·8												
NEUROSURGERY	77·6	52·2	50·7	13·4	22·4	26·9	35·8	16·4		1·5	35·8	44·8	3·0		10·4		7·5					3·0			6·0		
GYNAECOLOGY	83·8	21·2	64·0	19·5	11·5	5·9	3·2	52·2		0·3	17·1	68·1			3·5					0·3					3·5		
OBSTETRICS	75·7	16·2	51·8	29·8	7·4	5·9	0·4	33·1		0·7	12·9	75·4			3·7										0·7		
PSYCHIATRY CHILDREN	75·0	50·0	37·5		37·5		12·5								12·5	25·0						25·0		37·5			
NEUROLOGY	83·9	88·5	60·9	18·4	66·7	46·0	28·7	12·6		4·6	11·5	27·6			31·0		24·1	5·7		2·3	2·3	8·0			12·6		
TOTAL	73·9	48·9	53·1	29·5	33·6	19·5	12·0	28·9	0·1	2·3	17·9	45·0	1·1	0·2	21·9	0·1	2·8	0·4	2·3	0·7	0·3	0·8	0·4	0·1	3·4	0·1	0·1

FIGURE 10

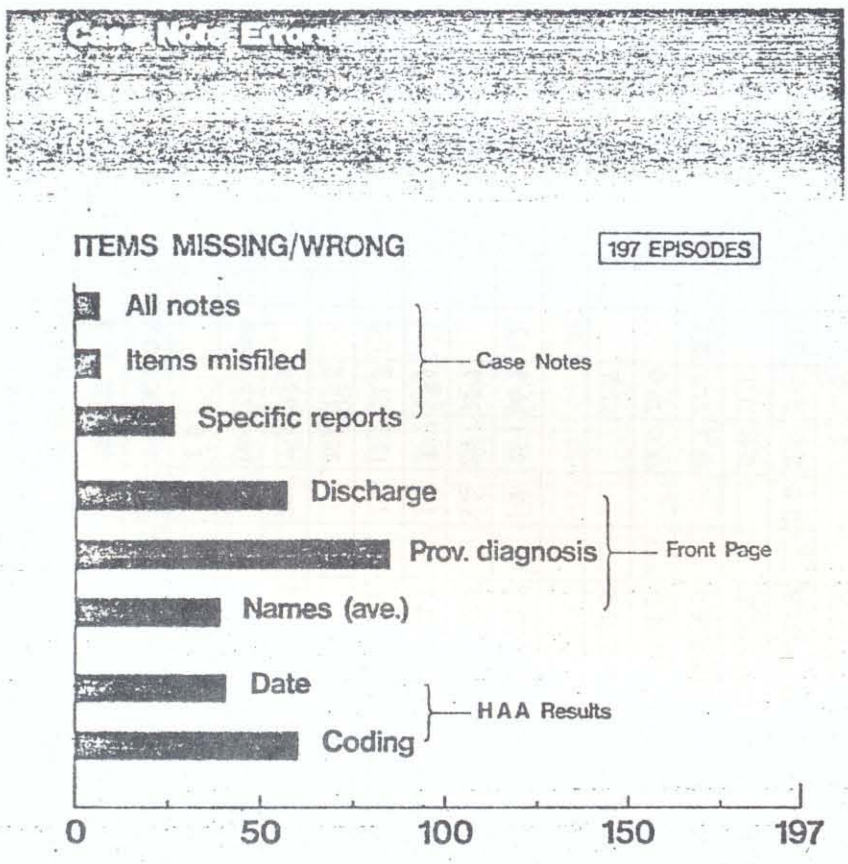

Case Note Errors
ITEMS MISSING/WRONG
197 EPISODES
All notes
Items misfiled
Specific reports
Case Notes
Discharge
Prov. diagnosis
Names (ave.)
Front Page
Date
Coding
HAA Results
0
50
100
150
197

FIG. 11 PATIENT STATES

	AWAITING				
	Results	Decision	Treatment	Discharge	Having Treatment
General Medicine	23.4	12.3	5.2	11.7	47.7
General Surgery	6.9	11.2	18.8	6.8	56.3

OCT. 1973: ESTIMATED AVERAGE DAILY NUMBER OF ACTIVITIES

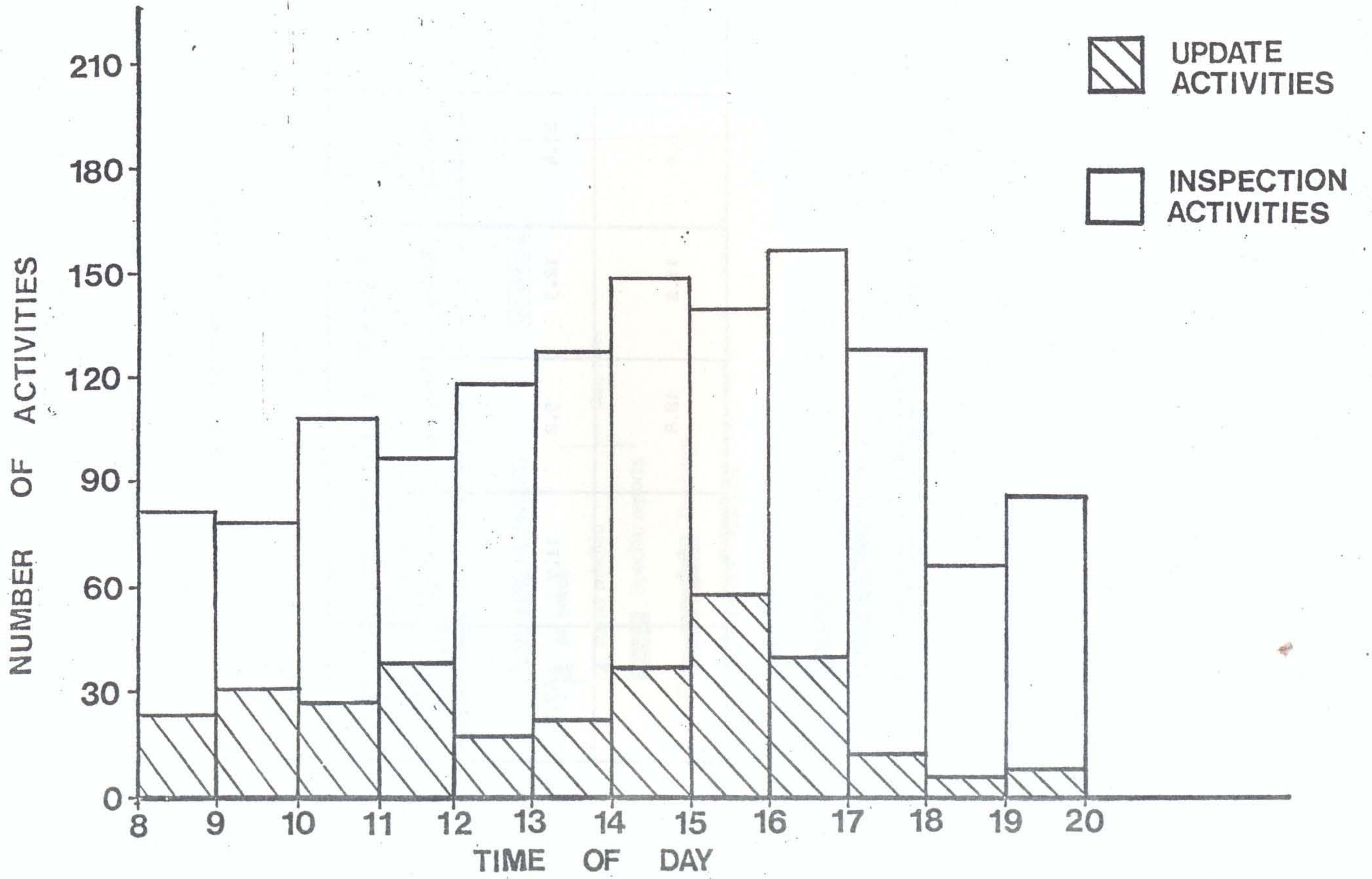


FIGURE 12

FIGURE 13

JUNE 1974: ESTIMATED AVERAGE DAILY NUMBER OF ACTIVITIES

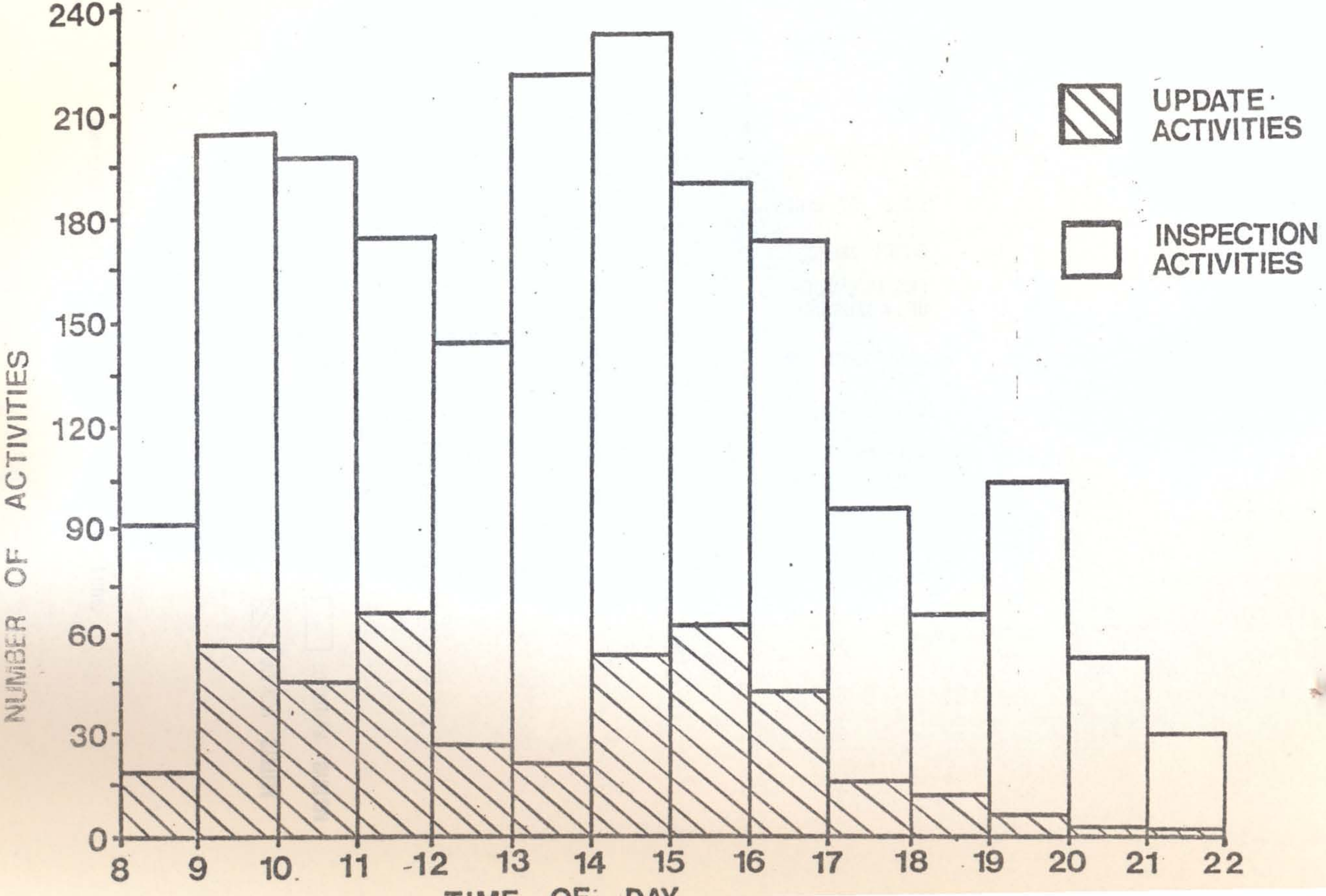


FIGURE 14

ENTRIES PRESENT IN SAMPLE OF 100 FROM DIFFERENT WAITING-LIST SYSTEMS