A COMPUTER SIMULATION OF THE ADMISSIONS AND SCHEDULING SYSTEM AT ST. PAUL'S HOSPITAL

by

MARK GORDON CHASE
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Department of Mathematics (Institute of Applied Mathematics and Statistics)

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date September 23, 1977

ABSTRACT

In this work, the admissions and scheduling system at St. Paul's Hospital was examined by means of modelling and computer simulation.

The Hospital is an acute-care facility with very high occupancy and a policy of admitting all of the emergency patients who require hospitalization. It now faces the problem of providing space for these patients without seriously disrupting scheduled admissions.

After investigation of the literature, it was decided to model the Hospital's admissions and scheduling system and use computer simulation to investigate its behaviour. Patients, operating rooms, and bed areas were classified by "hospital service". A GPSS simulation model which uses empirical data and a one-day time unit was developed. The model was verified and validated.

Several experiments were performed to suggest different methods to regulate occupancy in the various hospital areas, and to alleviate surgical slate disruptions, under existing or hypothetical arrival patterns for patients. These experiments were only a sample of those for which the model may be used.

Suggestions for extensions of this project are included.

In conclusion, two points are made: first, there are several contrasts between formal hospital policy and actual practice as revealed by the data; second, it appears that

simulation can be useful in a hospital context.

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ABBREVIATIONS

CPHA	Commission on Professional and Hospital Activities
DU	Direct Urgent
EENT	Eye, Ear, Nose, and Throat
El	Elective
ENT	Ear, Nose, and Throat
FIFO	First In, First Out
GPSS	General Purpose Simulation System
H-ICDA	International Classification of Diseases - Appended (Hospital Version)
ICN	Intensive Care Nursery
ICU	Intensive Care Unit
LOS	Length of Stay
OR	Operating Room
PAR	Post-Anaesthetic Recovery Room
PAS	Professional Activity Study (of CPHA)
SU	Semi-Urgent
U	Urgent

CHAPTER 1 INTRODUCTION

1.1 What Was the Problem?

St. Paul's Hospital in Vancouver, British Columbia is an acute-care hospital with a high occupancy level (an average of 93% overall, but near capacity in most of the Medical / surgical areas on weekdays). There is a shortage of beds, but the hospital admits all emergency patients who need to enter - although they must often be placed in "off-service" beds. Unless these patients are transferred out of the "off-service" beds, they often cause the cancellations of schedulable patients who should have been placed there. On the other hand, St. Paul's has more operating rooms than it needs.

This thesis discusses a study of the patient admissions and scheduling system at St. Paul's Hospital. A computer model of the system was designed for experimentation with different methods to regulate occupancy in the various hospital areas, and to alleviate surgical slate disruptions, under existing or hypothetical arrival patterns for patients.

1.2 Chapter Outlines

Chapter 2 discusses the background of the project. By providing details of the purpose and motivation for the project, it demonstrates that the undertaking was intended to be practical rather than theoretical.

Chapter 3 is an overview of the literature which was pertinent to the development of this project. Most of the chapter describes existing mathematical models of various hospital facilities, with a particular emphasis on computer simulation models.

Chapter 4 discusses the interpretation of the St. Paul's Hospital problem and the methodology which was used to investigate it. Basic methodological decisions which were made are presented, together with an explanation of those features which differentiate this project from those described in the literature.

Chapter 5 is an in-depth explanation of those facilities and processes in St. Paul's Hospital which are relevant to the development of the model. Particular attention is paid to the admission and surgical scheduling processes.

Chapter 6 presents the major information patterns in the hospital, by means of a set of flowcharts.

Chapter 7 is a discussion of the data and information from St. Paul's which were used in the model. Aspects of both the collection and analyses of these data are pointed out.

Chapter 8 describes the actual computer implementation of the model. Noteworthy concepts are explained, and there is a brief summary of the details of the model.

Chapter 9 is an evaluation of the simulation model. First, the form of the output of the model is explained. Then, details of the verification and validation of the model are provided.

Chapter 10 describes several experiments which were performed with the model, and analyzes their results. The selection of these experiments was intended to demonstrate part of the range of situations which the model may be used to investigate.

Chapter 11 suggests several ideas to update, extend, and experiment with the model in the future. In particular, the model may be improved and made more practically useful by means of newer data and renewed discussions with St. Paul's administration.

Chapter 12 is a concluding discussion. Two points are made: first, the data reveal a few lapses in the hospital system between formal hospital policy and actual practice; second, from my vantage point it appears that simulation can be useful in a hospital context.

CHAPTER 2 PROJECT BACKGROUND INFORMATION

This chapter briefly describes the early history of the St. Paul's simulation project. This background demonstrates that the basic motivation behind this undertaking was practical rather than theoretical.

2.1 Conception

The idea of applying the techniques of modelling and computer simulation to problems of St. Paul's Hospital arose from discussions between Mr. Brian Curtis (Head of the Management Engineering Unit of the Greater Vancouver Regional Hospitals) and Dr. Charles Laszlo (Associate Director of the Division of Health Systems at UBC). Mr. Curtis listed several objectives and data requirements of such a model. A general flow diagram was also produced.

The spirit of these suggestions was maintained in building the actual model, and therefore they are included in Appendix 1.1. The main objective was to model patient flow in and through the hospital. Experiments with the model would serve as guides for controlling the admission rate and placement of patients in order to regulate occupancy and to alleviate surgical slate disruptions.

2.2 Initiation

After the initial discussions, the project was not pursued further for about a year because manpower with suitable technical ability was not available. In May 1976, I became familiar with the project and decided to undertake its development within the framework of a Master's Thesis program in Applied Mathematics.

The first task was to clarify the interaction between admitting physicians (and the Emergency Unit), the Admitting Office, the Operating Room (OR) Booking Office, and the bed areas. A revised version of the original general information flow diagram, which connects these entities, appears in Appendix 1.2.

The second task was to establish the terms of reference of the working relationship with St. Paul's Hospital. Therefore a proposal was submitted to Dr. Van Tilberg, Medical Director of the hospital (Appendix 1.3), suggesting investigation of problems of allocation and utilization of operating rooms, beds, and Medical personnel, and scheduling of surgical patients. The actual development of the project closely followed this proposal.

Ready support, sprinkled with some skepticism, was forthcoming from several administrative levels. We were given permission to proceed with the project, and were assured of access to key personnel and data.

2.3 Initial Familiarization

The rough draft of a working paper on admitting at St. Paul's (Brian Curtis, May 1976) and studies done on OR statistics (Lee and Westerheim 1974), on bed allocation and booking (Gallager 1973), and on transfers (Scroggs 1970) served as the starting points for understanding the system at St. Paul's. There was also a large data file drawn from patient case abstracts (see Section 7.1.3), which was to prove valuable in providing length-of-stay (LOS) information.

Furthermore, I was introduced to knowledgeable personnel in the Admitting Office, OR supervision and booking, the Emergency Department, and the Medical Records Library.

2.4 Practical Applications of the Model

From the practical point of view, the model is intended to produce a realistic simulation of events in the hospital as certain system parameters vary. These variations may arise either in a controlled manner due to modifications in hospital policy or structure, or in an unexpected fashion due to changes outside the hospital environment. Thus, the model is expected to produce responses to various "questions" which might be imposed by such situations. For example:

- Can the allocation of beds to services be altered to increase the throughput of patients?
- If the number of patients increases, what happens to the

waiting list?

- What happens if some of the OR's are closed?
- What impact would an increased number of patients have on the volume of surgeries per room and number of "No Bed" occurrences?
- What happens if emergency admissions vary in number?
- What happens if in-patient transfers vary in number?

A more detailed list of questions may be found in Appendix 1.4.

CHAPTER 3 LITERATURE REVIEW

Extensive literature exists on all aspects of the application of operations research techniques in hospitals. For example, in their book, Operations Research in Hospitals: Diagnosis and Prognosis, David and Ruth Stimson include over 500 bibliographic citations. To review the studies done, they identify seven categories. One of these: "admission, discharge, and utilization of inpatient facilities" is of particular relevance to this project. A more recent study is Operations Research In Health Care: A Critical Approach, (1975) edited by Shuman et al. It includes a set of literature reviews which, without intending to be complete, include over 1000 bibliographic citations. The chapters on "simulation" and "stochastic processes" are particularly pertinent to this project. Anyone wishing to search beyond the range of this particular thesis is likely to find each of these books quite helpful.

Two other articles of a general or reference nature should also be mentioned. Milsum et al (1973) present a holistic analysis of hospital management admission systems. The authors include a useful tabular display of the characteristic features of eleven of the major modelling and simulation developments pertinent to their discussion. The most recent bibliography to appear on "patient scheduling" is that by Kohler et al (1977) which lists 163 papers relevant to the problem of waiting lines in hospitals.

This review is limited to those groups of articles which are specifically relevant to the development of this thesis. The first group is on hospital data and their analyses. The second group of articles provides early discussions on "forecasting bed needs". The third group is devoted to relatively sophisticated models of various aspects of hospital care. It includes stochastic models, a hospital-based study model, Young's queuing theory models, and models employing Markov processes. Various computer models are also reviewed in some detail.

Balintfy (1960) published one of the first discussions on the stochastic distributions related to hospital admissions and discharges. He argued on theoretical and empirical grounds that the distribution of daily arrivals, which could be considered a Poisson process, is more accurately described by the negative binomial distribution. He reasoned that the distribution of LOS should be lognormal, which compares well with his observed data. Finally, he suggested the negative binomial distribution for daily discharges. From these, he described the possibility of predicting changes in the system.

Admissions to a casualty ward were analyzed by Pike et al (1963). They noted transfers and short-stay patients and analyzed admission numbers by day-of-the-week and by month. They found that a good "fit" to empirical data was obtained with a Poisson distribution for daily arrivals and a geometric distribution for LOS. A Poisson distribution then resulted for the number of beds occupied.

McCorkle (1966) did an extensive graphical presentation of in-patient LOS in various hospital departments. Besides the various Medical and surgical specialties, groups were subdivided according to treatment by a staff or private physician.

Lew (1966) tested the statistical significance of certain variables which relate to admissions, discharges, and LOS, and might seem unimportant to a patient's health care. For example, he found that the day-of-the-week of admission had a significant effect on LOS, that the admission diagnostic category of a patient had a small effect, and that the type of accommodation had very little effect.

Dunn (1967) reported on an admission scheduling procedure. The procedure accounted for such things as what the admission type (urgency) of the patient was, and which hospital services (such as OR procedures) were required. The computerized analysis produced graphs of the number of beds available over a two-year period.

In an efficient hospital it is desirable to have high average occupancy and infrequent overload or "No Bed" situations. Drosness et al (1967) considered the use of the daily census to optimize capacity. Their work was on a small hospital, but they suggested that for a large hospital the daily census data would change from fitting a normal distribution to fitting a truncated Poisson distribution.

LOS is one of the main variables affecting occupancy. Administrators who can predict LOS fairly accurately can do a more effective admission scheduling job. In 1968, David

Gustafson did a small comparative study on five methods of estimating patient LOS. These were direct estimates by the physicians, regression analysis, historical average, direct posterior odds estimation, and Bayes' Theorem with three variations. The last method was the best. In it, the physician estimated the probability that a patient would be discharged on a certain day, given demographic and symptomatic characteristics. He did so by suggesting the likelihoods of these "independent" characteristic features, supposing that the LOS was already known. This prediction method required some training and took time for the physician. Gustafson explained why the subjective methods were better. Training and on-line computer facilities could substantially reduce the physician time involved.

Also in 1968, Bithell and Devlin presented a study on prediction of discharges. They discussed the accuracy of initial LOS estimates by the physician, and the improvement caused by revision of these estimates periodically during the patient's stay.

LOS in a mental hospital was the subject of Hanson's model in 1973. He found the LOS distribution to be lognormal, and used separate means and variances associated with different diagnoses.

Forecasting of bed needs is the sole topic of the following three early papers. Most of the subsequent papers also include that concern within their scope. In 1963, Johnson was pleased with a 90% accurate predictive method based on area population and historical patterns. Beenhakker and Brooks (1964) developed a much more powerful method for predicting bed needs in seventeen classifications, by regression analysis on 117 factors! In a study of the demand for hospital beds in various regions of England, Newell (1964) discovered that the supply of hospital beds affects the demand for them. It has been suggested that the adjustment is effected via patient LOS. As a result, Newell doubted the ability of queuing theory models to yield useful estimates of bed requirements.

There have been many models developed for different aspects of a hospital's operation. This thesis is concerned primarily the analysis of a particular hospital. The work of Shonick, however, deserves mention for its generally applicable calculations oriented to area-wide planning. His models considered emergency and elective arrivals at a Poisson rate. LOS was taken from a negative exponential distribution. Optimization of the bed complement was with respect to percentage occupancy, overfill, and queue size. Shonick (1970) used this model to develop census, queue length, and waiting-time distributions. In 1973 Shonick and Jackson improved the model by incorporating a cut-off point for a specific number of beds above which electives would be made to wait and only emergencies would be admitted, and by adding a variation wich permitted emergency overflow to an unlimited number of "non-approved" beds.

In their book <u>Computing and Operational Research at The London Hospital</u> (1972), Barber and Abbott include a chapter on operational research studies of which one is an "admission-discharge study". A multi-disciplinary group within the hospital worked from 1966 to 1969 to define a model and to alleviate problems related to high occupancy. The group actually implemented several system modifications, and examined the results. They found that the best measure of the strain on the system was the number of avoidable transfers. The study concluded that "the reduction of the level of acceptance of waiting list admissions is the only overall control open to the administration". (Page 40, Barber and Abbott, 1972)

Young was probably the first to apply formal mathematical analysis to the problem of occupancy stabilization given elective and emergent patient streams. In 1965 and 1966 he presented a queuing theory model with parallel service facilities (beds) and two parallel input streams, one corresponding to emergency arrivals (at a Poisson rate), the other to elective (scheduled) admissions in an L-phase Erlang process - which may represent deterministic or Poisson rate arrivals. The LOS is taken to be distributed as a gamma variable. Young compared a rate-control model and an adaptive control model. In the first, the input rate of scheduled admissions was set. Standard methods of analysis yielded overflow and turnaway probabilities. In the feedback control model, scheduled arrivals constituted a deterministic stream which depended on the occupancy. Scheduled admissions were brought in to keep the hospital at a certain occupancy level, but above that cut-off point no scheduled admissions were allowed. Again, standard queuing theory equations for "birth and death processes" yielded steady-state probabilities. Unfortunately, Young's assumption of exponentially-distributed LOS (service time) and inter-arrival times are usually unsatisfactory representations of reality.

Bithell (1969 a & b) used Markov processes to study the same situation as Young had. His first paper developed pertinent statistics to aid in analysis. He found that for deterministic admissions, the variance of the occupancy was proportional to the standard deviation of the LOS. For elective admissions based on a continuous appraisal of the current bed-state, the occupancy variance equals the emergency admissions variance plus a factor depending on the variability of discharge. In the second paper, he discussed the advantages of using discrete-time (Markov) processes, and tailored the two models to particular week-day events. The "adaptive control" model was found to reduce the occupancy variance significantly, contributing to improved efficiency.

In 1970, Kolesar further refined Young's model, with a Markov decision aspect and a linear program. He first pointed out that if Young's Poisson processes are replaced by more general ones, and if the control rules are made more complex, queuing theory analysis collapses. Kolesar steered clear of computer simulation, since he considered them to be very difficult and often only specifically applicable to the situation studied. (He admitted simulation was potentially fruitful - citing Fetter and Thompson's work.) He preferred a

Markovian model for its flexibility in the use of distributions and decision rules. That method can obtain "good" rules efficiently. Incorporating a linear programming problem, he posed such problems as: How many patients should be scheduled for admission each day in order to:

i. maximize average occupancy with an overflow constraint, and

ii. minimize overflow with utilization constraints?

Kolesar even mentioned the minor variations necessary to simultaneously schedule for several services. Results could be listed in a decision table as an administrative aid.

Markovian analysis has also been applied to other related fields. Thomas (1968) applied Markovian analysis to coronary patient recovery, identifying four recovery states each subdivided into three phases to account for the time in each state (since Markov processes are memory-less). From his LOS analysis he found that patients who recover have a lognormal stay distribution, while those who die have a negative exponential one.

Kao (1972) decided that Thomas's model with its awkward "phases" should be refined. He added a holding time according to the LOS distribution in the four states, yielding a transient semi-Markov process model. His model even predicted the census mix.

In 1973, Kao considered the patient's path of movement within a unit. In a 1974 paper, Kao used both a Markov renewal process and simulation to decide whether to admit a patient to a coronary care unit or to treat him elsewhere in the hospital, with the objective of minimizing mortality.

Another Markovian analysis, interesting for its output variables, dealt with a geriatric ward. Meredith (1973) developed a simple model considering five main states, with their transition probabilities and costs. Some of the output variables were recurrence time, cost until death, and expected stay.

The remainder of this review is devoted to computer models which are simulations for the most part, but some which are designed for adaptation or direct use on-line in an Admitting Office environment. It is interesting to note that, of the simulations for which the language used was noted, GPSS, SIMSCRIPT and FORTRAN had roughly equal usage.

The most frequently cited studies are those by Fetter and Thompson, who in 1965 presented a three-part SIMSCRIPT simulation of a maternity suite, a surgical pavilion and an outpatient clinic. In the maternity suite they found that if a proportion of the admissions could be scheduled, it would smooth occupancy and reduce bed requirements. In 1969, they proposed a model of an entire progressive care hospital in which the patient moved through different zones depending on his state of health. They argued that if the probability for changing zones depended only on the present zone occupied, Markovian analysis would suffice. However, since it also depends on the admission zone and the history of zones occupied, simulation was necessary. One output of this GPSS simulation was a set of probabilities for various levels of bed utilization in each zone. The results of the simulation defined parameters for a budget-constrained linear programming model designed to optimize overall bed utilization.

The US National Center for Health Statistics produced a computer simulation of hospital discharges in 1966. The Center had previously started a Health Interview Survey used to estimate the number of annual hospital discharges, and wished to use the simulation to examine the factors causing discrepancies between the response and reality in order to improve the survey. The choice of stochastic distributions may be of interest. The annual number of hospitalizations for an individual was taken to be the outcome of a Poisson process, whose parameter was considered to vary over the population as a gamma variable. Hence, the population's number of hospital episodes per year was negative binomial in distribution. LOS was found to be lognormal, with the discharge probability conditional on the time already spent in the hospital.

Handyside and Morris (1967) simulated an emergency department. They were satisfied with a Poisson arrival rate, but felt that empirical LOS data did not fit distributions proposed in the literature. The department being considered had operated only when it was needed. The authors examined the effects of various policies which defined the sequence of days of use on the stabilization of bed occupancy.

A SIMSCRIPT simulation of a multiple OR system, by Barnoon and Wolfe, appeared in 1968. Their hospital had limited beds but excess operating rooms. They assigned an OR, an anaesthetist and nurses to cases (after bed selection). By placing values on each of these services they examined the costs of various alternatives.

Robinson et al (1968) evaluated three scheduling systems with a total of six variations and compared the average daily costs of operation (in terms of empty beds, overflow and turnaway) at their optimal operating levels. The simulation consisted of three phases: a request generator to produce patients and their attributes, a section to schedule these patients, and an evaluation section to find the optimal operating level for given costs and a given scheduling rule. The first two sections were written in SIMSCRIPT and the last in FORTRAN. Only elective patients were considered. The authors thought that a reasonable policy to account for emergency patients would be to merely allocate them a fixed block of beds and to proceed as before. The number of beds was taken to be the only scheduling constraint. It was suggested that OR booking could be implemented by using available operating time to define or modify the patient's desired admission day. Each patient was "generated" with an earliest possible arrival date and latest possible arrival date assigned on a fairly arbitrary basis, since no data were available. The three basic scheduling alternatives were:

i. "Filled page", which is analogous to using a book to record scheduled admissions, by writing a patient's name into the first requested day that has an open entry.

ii. A method which used an estimated LOS as if it were exact, and projected the census. The patient was scheduled for the earliest requested day for which his addition would not overload the hospital census.

iii. A method which had a probability table to incorporate conditional probabilities of actual LOS given the estimated value. It was an extension of the above method, admitting the patient according to "expected census" figures.

Variations in the scheduling system allowed for different levels of accuracy in the estimation of LOS. The second method with good estimates, or revisions allowed, performed best. It was noted that patients desiring admission quickly were often turned away. It was suggested that the scheduler program could be the core of a real-time patient scheduling system.

Goldman et al (1968) studied various bed allocation policies in relation to utilization levels, using FORTRAN IV. They begin their discussion with the following noteworthy comments:

> "It can be mathematically shown that the policy of allocating beds in any manner leads to a degradation in overall utilization. Why, then, allocate beds? The principal advantage of bed allocation is the potential efficiency to be derived from grouping patients with similar health problems in the same physical area, convenient to the facilities and services they require. Patient grouping also allows hospital personnel to develop specialized skills in the performance of their patient care functions; and since the practice of Medicine is subdivided in the same manner, the physician can decrease his travel time between patients by concentrating his patients in one physical area."
>
> "In some circumstances, the Medical condition of the patient dictates isolation in a private

> room; and social custom dictates the separation of patients by sex and possibly by age. Patient preferences and financial considerations may also be involved.
>
> Some obvious disadvantages are associated with any allocation policy. Among these are (1) a possible reduction in total bed utilization; (2) a potential increase in patients waiting for admission; (3) transfer problems created by the attempt to maintain any type of patient segregation; (4) a potential increase in the number of emergency patients placed in temporary beds (over-capacity beds) owing to extremely high utilization in any one service; and (5) a potential decrement in patient care when a patient is placed in another service because of high utilization in his proper service." (Pages 119-120, Goldman et al, 1968)

In view of these considerations, they considered three beds-to-service policies and three beds-to-rooms policies. The beds-to-service policies were based on some services being "restrictive" (Obstetrics, Intensive Care) and some "unrestrictive" (Medical, Orthopedics) in the sense that they respectively were or were not allowed the use of beds in other service areas. The three policies were differentiated according to the proportion of time the allocated beds would meet the restricted services' demand. The three beds-to-rooms policies defined (i) all beds to be in private rooms, (ii) beds to be in various types of rooms as determined by average demand, and (iii) as many beds to be in wards as possible. Together these gave nine bed allocation policies which were tested at several levels of overall bed utilization. Emergent, urgent, and elective admissions were allowed. Bed utilization, waiting times, overload, and transfers were recorded. General conclusions were that at high levels of bed utilization (about

95%), any attempt to satisfy demand in the restricted services resulted in extremely long waiting time, and a large number of private rooms would be desirable under cost parameters of the sort used in the study. Their study was carefully developed mathematically and warrants attention by those interested in the topic.

An evaluation of operating room scheduling policy was published by Goldman _et al_ (1969). Simulation was used so that many policies could be examined quickly and without disruption of the real system. They considered three policies for daily scheduling: (i) first-come, first-served; (ii) longest-cases-first; (iii) shortest-cases-first. Two levels of expediting (that is, percentage of cases capable of being moved to a somewhat earlier starting time) were incorporated. Data were from a 380-bed, 63% occupancy hospital. The simulation was in FORTRAN IV, with a five-minute time increment. The simulation assumptions and a flow diagram were presented in the paper, together with a useful tabular discription of important input and output data. The authors used three levels of capacity (possible total time to schedule) and examined among other things utilization, overtime, unused time, rescheduling, and waits. The longest-cases-first policy gave highest utilization and lowest total daily overtime for all levels of expediting and capacity.

The ORSA Bulletin abstracted a paper given by Shao and Thomas in 1970, which may be of interest. Their model considered elective, urgent and emergent patients, and recognized dependence of the arrival distribution on the day-of-the-week, so the system was treated as a special Markov process. The model considered effects of different admission strategies (including priority schemes) on non-emergent waiting times. A simulation was performed.

Hearn and Bishop produced a different sort of simulation in 1970. Using two wards, they considered 200 kinds of service items. They looked at variations possible under a no-delay system, scheduling, a seven-day week, and progressive care.

Connors (1970) presented a simulation model in PL/1 which he intended for eventual use in a real-time Admitting Office environment. The algorithm for scheduling patients was quite involved. It used deterministic constraints arising from the patient's characteristics and requirements. Additional probabilistic constraints were based on the hospital's operating requirements with the random processes of arrivals and occupancy. Feasible admission date and accommodation combinations were hence identified. The algorithm chose from among these combinations in order to minimize a composite function, called the figure of merit, based on patient inconvenience and hospital inefficiency. For each patient, only the appropriate service was analysed. The patient LOS assigned by the program was calculated from a gamma density function using Commission on Professional and Hospital Activities (CPHA)-supplied mean and standard deviations. Provision was made for alternatives such as physician estimates (with update capability) or hospital empirical data. Each admission request had to be accompanied by a list of patients' preferred days for admission, and the type of accommodation desired. The algorithm could be run in any of several modes. Under the ADMIT mode, it entered the patient in the admissions log at the date for the lowest figure of merit (if suitably small). Under the NO ADMIT option, it listed up to ten feasible days which might then be offered to the patient for choice. Under the PRIORITY ADMIT mode, any arbitrary admission day could be reserved. Once a day was selected, the program performed appropriate updating calculations, and awaited another request. A patient MOVE could also be entered. The algorithm did not, when the article was written, incorporate OR scheduling. This scheduling decision was made independently, causing surgical admissions to be done by a NO ADMIT / PRIORITY ADMIT mode sequence. Special care units and a large number of transfers would complicate and reduce the effectiveness of the algorithm.

A paper by Blewett et al describing the joint use of wards and an operating theatre by ENT and Opthalmology consultants appeared in 1972. Admissions were taken to follow an empirical statistical pattern and were uncontrollable. Patients were categorized for homogeneity of lengths of surgery and stay. Models were developed, and written in FORTRAN, for Opthalmology alone, for ENT alone, and for the two sharing facilities with one another. A validity comparison of the models and the real system was tabulated. Three experiments were performed with the validated models. One experiment, with the Opthalmology model, checked the consequences of a new minor operating theatre on bed use. The second experiment, with the cmbined model, examined the effects of a change (actually under consideration) in the operating timetable. The third experiment concluded that with combined rather than separated specialties, the use of temporary beds would be reduced without decreasing overall throughput. An unusual claim of this study is that its conclusions were considered by management with favourable results.

Schmitz and Kwak have produced a series of papers on the simulation of surgical units. In 1972 they used a manual simulation to consider the effect of increased beds on operating-room and recovery-room usage. They examined what the bed increase would mean in terms of the number of procedures, and in terms of time and capacity in the OR and recovery rooms. Kuzdrall joined the authors, and in 1974 a GPSS extension of this manual simulation appeared.

Their most sophisticated work appeared in 1976. It involved a comparison, via GPSS simulation, of five possible patient flow strategies, each with "real - world" foundations. Again, a surgical suite and recovery suite were the physical facilities under consideration. Empirical data were used to determine length of surgery and LOS distributions. The strategies compared were:

i. random input to surgery (existing policy);

ii. preemptive priority for recovery-room users;

iii. longest surgery first within recovery-room users, then within non-recovery patients;

iv. longest surgery first for recovery patients, others random;

v. longest surgery first within major procedures, then others needing the recovery room, then the rest.

Surgical suites were treated together as a single facility rather than individually, to minimize ambiguity. It was found that utilization could be improved and that the length of the working day in the recovery-room could be reduced (up to 21%) by using a new strategy. The hospital under consideration was increasing its surgical load anyway, and seriously considered implementing strategy (iv) to minimize the additional requirements of such an increase. However, another option beyond the range of the study appeared and was eventually chosen.

In the Computer Medicine newsletter of April 1977 an entry appears concerning a "Computer Aiding Surgery Schedule". It states that a new system (first tested for two years) is now implemented to align patients and personnel in a 26 - OR hospital. The computerized scheduling system saves a considerable amount of time, can be corrected or changed by staff, and will probably be expanded to retrieve some information. No further details of the system are published at present.

The preceding review is by no means exhaustive. Outpatient departments and scheduling of nursing staff, for example, have not been included at all. Nevertheless, the reviewed articles provide a fair overview of the literature which is applicable to the work presented in this thesis.

It may be of interest to point out the sources and range of dates of the articles presented here. Of the 45 cited, 12 were from Health Services Research, 6 more from Operations Research and 4 from Management Science. Twenty other sources yielded the remainder, with 12 articles from Medical areas, 7 from Management Science, Operations Research, or Statistics, and 4 from Computing or Engineering references. 1970, 1972 and 1973 contributed 5 articles each, plus 6 from 1968. There were 7 from 1960 through 1965, 7 from 1966-67, 4 from 1969, and 6 since 1973. In aggregate, over two-thirds of the articles appeared from 1966 to 1973, including one-third from 1968 to 1970. At present, a great deal of applied work is being conducted by both hospital-based and outside consultation groups who have little incentive to publish. Furthermore if, as suggested by Shuman et al (1975), future studies are more large-scale - including the problems of subsystems and their boundary interactions - then new contributions to the literature can be expected to become more infrequent, but more significant.

CHAPTER 4 INTERPRETATION AND METHODOLOGY

The literature review of the preceding chapter demonstrates that several different mathematical approaches have been used to model problems similar to ours. These approaches include stochastic, queuing theoretic, Markovian and simulation methods. Within each of these, the model may be considered in a variety of ways. This chapter presents the basic methodological decisions made for the St. Paul's Hospital project, and proceeds to discuss them in the context of the analyses just reviewed.

4.1 Basic Methodological Decisions

4.1.1 Mathematical Method

The generalized stochastic analysis approach, as undertaken by Shonick (1970) and Shonick and Jackson (1973) was rejected since, as they stated, it is oriented towards area-wide planning for a community rather than for a specific hospital. The results of the present work are intended to be of use to St. Paul's Hospital in Vancouver with its particular characteristics. If the model turns out to be more generally applicable, that is an additional benefit.

Queuing theory as used by Young (1965,1966) is also unacceptable since it is highly unlikely that arrival rate and

LOS distributions can justifiably be represented by Poisson processes. (See Kolesar, 1970; Blewett et al, 1972; Schmitz et al, 1976.) Furthermore, the scheduling process at St. Paul's - which requires OR slates to be planned ahead with some flexibility and which has various degrees of urgency for admission - is rather complex, and not amenable to a queuing model.

Markovian analysis seems more promising. It maintains the convenience of a closed form solution while still being quite flexible. Empirical data can be used. Kolesar (1970) added an interesting idea in incorporating a linear program. Kao (1972) showed that LOS could be accounted for realistically. However, the problem we have posed is not suitable for Markovian analysis. We are not interested in a number of consecutive patient states - as in a progressive care hospital. Even if patient states were defined as, say, (i) awaiting admission, (ii) occupying a bed off-service, (iii) occupying a proper bed, and (iv) discharged, problems would still remain. One intent of our project is to discover the impact of certain scheduling and bed-complement variations on the waiting line. It is not clear how to include OR scheduling, or any other sort of flexible bed scheduling in a Markovian model. It would probably not be possible to demonstrate the vital interaction between OR scheduling and the Admitting Office, with its important "No Bed" variable as output.

Simulation, on the other hand, can be used to model very complex situations. Its use in transportation, economic and energy models is quite familiar. Furthermore, its application to health care has been demonstrated to some extent (see Stimson and Stimson 1972, or Shuman et al 1975). Simulation can be used to model the patient admissions and scheduling system at St. Paul's Hospital.

4.1.2 Language

Having decided to use computer simulation, one must choose among a number of languages. Reitman's article on simulation languages (1967) gives some useful pointers. The possibilities were a higher order language (FORTRAN) or a generally available simulation language (GPSS, SIMSCRIPT or SIMULA).

FORTRAN was quickly eliminated from consideration. Since it is not a specialized language, if FORTRAN were used the model would be expected to be cumbersome. List processing in the language is weak - a definite disadvantage with diverse "lines" of patients awaiting admission and operations. There is no statistical processing built in.

It seemed, then, that one of the main-line simulation languages would be best. Of the three mentioned, SIMULA was suggested to have the best capabilities. However, when this project was being considered, it seemed that UBC was going to stop its support of that language.

SIMSCRIPT seems to be a good language for large models. Its time-stream and event-oriented structure are convenient, as are language constructs for data. However, there are disadvantages. The amount of computer memory that the SIMSCRIPT processor will make available is uncertain, and large models become inefficient and require skill in programming. Consultation and support at UBC is limited. Furthermore, compared to GPSS it tends to be expensive, and has poorer diagnostics.

GPSS also has pros and cons. On a surface level, the block structure suggests what is happening. However, much of the internal working is disguised. This may be alleviated somewhat by the GPSS provision for incorporating documentation with each line of code, to explain the model. Statistics which are maintained internally cover all the usual output demands, and tables may be added conveniently. GPSS models can be very large - although they do get expensive. UBC gives GPSS "major" support with good consultation, regular updates, and quick attention to system bugs. (This last point did prove worthwhile.) The language processor tends to be fairly efficient, and the language is well-known.

Such considerations led to the choice of GPSS as the simulation language for this project.

4.1.3 Time Unit

Depending on the level of detail involved in the simulation of each day's activites, different time intervals may be desirable. (The simulation languages which we considered use a discrete rather than continuous time stream.) Goldman _et al_

(1969) used a five-minute time interval for their OR study. Our study, on the other hand, is not intended to consider the minute processes of the OR. In fact, the OR is mainly of interest for the number of patients scheduled there per day. Similarly, bed turnovers are normally on a day-to-day basis. As result, the time unit chosen was one day. Although a number of events must happen in sequence each day (eg. discharges and admissions), this can be simulated by assigning "priority levels".

4.1.4 Level of Aggregation

One must decide which hospital facilities to represent and how completely to differentiate patients according to their care needs.

The problem as posed involved OR's and beds. These facilities should be adequate for considering most questions involving patient flow and scheduling.

A classification system based on "hospital service" can be set up to match patients to the appropriate OR, bed area, and physician specialty groups (see also Section 5.1.1). A further subdivision of patient types according to H-ICDA diagnoses and procedures may be possible. However, it would require extensive consultation with a group of experienced hospital administrators to group these codes into a manageable number of homogeneous patient groups. Furthermore, such subdivision would complicate data collection.

4.1.5 Extent of the Model

Should every hospital unit be included in the model? How much staff should be shown? These are other questions which may be answered in general terms at the outset.

It is quickly evident that the Day Care, Psychiatric, Renal and Nursery units operate effectively independently of the basic Medical / surgical function of St. Paul's Hospital (see also Section 5.1.1). This high-lights the fact that the essential matter of interest is the rate of patient flow. Only units which are involved in the control of this rate (as through operations, beds, and bed transfers) need to be considered for inclusion in the model.

It should be safe to assume that the hospital will employ whatever nursing complement is necessary to handle the patients who arrive there. As a result, nurses are not identified as separate entities in the model. This merely suggests that the size of the nursing staff does not determine the number of patients at an established hospital, under normal labour conditions, but vice versa. As is noted in Section 5.3.7, nursing considerations do contribute to explaining the efficiency of handling operations, particularly emergencies.

With a bit more hesitation it was decided to exclude anaesthetists from the model. The one-day time unit and the realistic assumption that the hospital would ensure that the number of anaesthetists was appropriate to the service pattern, account for this decision.

4.2 Distinctive Features of this Project

St. Paul's desired a model of its patient admissions and scheduling, and the literature contained several approaches to hospital modelling. Would it have been possible to adopt one of the existing models to the problem at hand? The answer is no. The following section discusses features of this project which differentiate it from other related work published in the literature.

Probably the most outstanding feature of our model is that several "characteristic" hospital services are modelled simultaneously (presently Medicine, EENT, and Orthopedics are implemented). It is recognized that when beds are not available in the appropriate service areas, emergency admissions may be placed in alternate areas. This becomes significant when it is considered that about 75% of the Medical admissions to St. Paul's are on an immediate basis. There are so many immediate Medical admissions that about 30% of them must be admitted off-service. As a result, the model must transfer enough Medical patients out of surgical service areas to minimize "No Bed" cancellations (see Section 5.2.3).

Secondly, there are basically two main groups of admissions, schedulable and immediate (see Section 5.2.4). The schedulable cases form a waiting list, and are categorized and handled according to urgent (U), semi-urgent (SU) and elective (El) categories. (Very few other models differentiated within the schedulable stream.) However, in contrast to most other models, our model does not allow a trade-off of the "probability of being able to handle all emergencies" against "occupancy". All emergency patients are admitted, with the result that immediate admissions account for 45% of all admissions and 75% of the Medical ones. Still, occupancy is very high - an average of 93% for the whole hospital, and higher for the services described by our model.

Thirdly, the hospital modelled observes different admission methods for the different services. A Medical patient on the waiting list is admitted when a bed is available. A surgical patient is first scheduled for surgery, subject to certain limits, and is then admitted on the appropriate day if a bed is available.

Fourthly, we found that while in the past various parametric distributions have often been used to describe patient arrivals and LOS, such parametric distributions did not provide an adequate "fit". Thus, for added realism, we use empirical data to describe these processes.

Finally, this study is designed to indicate what effect (in terms of occupancy, bed availability for scheduled surgical patients, and waiting times) might be had by changes being considered at St. Paul's Hospital. Such changes include closing under-used operating rooms, restricting "alternate" placement of patients, and varying bed numbers or allocation.

CHAPTER 5 THE HOSPITAL AND THE MODEL

This chapter discusses those facilities and processes in St. Paul's Hospital which were examined in developing the model. The assumptions and detailed considerations of the hospital's physical structure and of decision processes pertaining to patient flow are described.

Hospital functional and locational subdivisions depending on patient classification and preference will be discussed first. This will be followed by the two principal topics of interest, admitting and surgical scheduling considerations. These two, supplemented by in-hospital transfer and LOS data, serve to determine patient flow through the hospital.

5.1 Definition of Subsystems

Obviously not all patients receive identical treatment at the hospital. Nevertheless, for our purposes most differences are not important and it is preferable to consider relatively homogeneous patient groups in the formulation of the model. There exist natural classifications called "services" which do this fairly well. The word "service" may define slightly different groups, depending on whether it is used in hospital records, or to describe an OR designation, a physician specialty, or a hospital area. From these classifications, I have developed a functional classification to be used in the model. We note that there are some special-purpose hospital units defined according to the care they offer rather than the patient's "service". Within a hospital area, it is possible to characterize beds further as being private, semi-private, or in a ward, and as being designated for a male or for a female, or for either one.

5.1.1 Hospital Services

When an admission request arrives at the hospital, two things must be determined: where the patient should be located and, if applicable, in which OR his surgery should be performed. The daily census sheet divides the hospital into its 21 nursing stations (Table I). The OR Booking Office visual file and daily slate are subdivided into eleven sections corresponding to operating theatres or groups of theatres (Table II). To schedule and place a particular patient, a single classification scheme is most useful. There is an item referred to as "hospital service" on case abstracts kept by the Medical Records Library. (The coded abstracts are submitted to CPHA for analysis.) By regrouping the original codes for this item, we can obtain functional patient groups which we will call services (Table III).

One precautionary note should be added here. One service, General Surgery, divides its physicians, bed areas, and OR usage according to subdivisions "A", "B", and "C", which are referred to within the hospital as "services". The model does not

TABLE I

NURSING UNITS (JUNE 1976)

Ward	Use	Beds Priv	Beds Semi	Beds Ward	Bassinets	Rated Capacity
6 South	Maternity	19	2	10		31
6 South	Nursery				35	35
5 North	Gynecology	21	12	8		41
ICN	Nursery				14	14
5 South	Gen'l Surgery A	3	18	23		44
4 North	EENT	3	14	18		35
4 North	Orthopedics		10	16		26
4 East	Orthopedics	1	2	41		44
4 South	Urology	7	14	22		43
3 North	Medicine	4	16	12		32
3 Neuro	Neurology & Neurosurgery	3	4	16		23
3 East	Gen'l Surgery B	1	6	24		31
3 Main	Gen'l Surgery C		8	24		32
3 South	Activation			16		16
2 North (20 semi-closed teaching)	Medicine	20	20			40
2 East	ICU	8	4	8		20
2 West	Cardiac Unit	1	10	4		15
2 South A (18 semi-closed teaching)	Medicine	8	14	17		39
2 South B (all closed teaching)	Medicine			28		28
C2A	Psychiatry			10		10
C2B	Psychiatry			30		30

TABLE II

DAILY SLATE SUBDIVISIONS

Gynecology	Room 1
Room 2	General Surgery "service" A, B, or C (depending on day or need)
Urology (incl. Cystoscopy)	Rooms 3 and 4, and perhaps 5
Day Care	Room 7, and perhaps 5
EENT	Rooms 8 and 9 ENT M / W / F Rooms 10 and 11 Opthalmology T / Th
Open Heart and Vascular	Room 12
Room 14	General Surgery "service" A, B, or C
Orthopedics	Room 16
Room 17	General Surgery "service" B or C
Room 18	Neurosurgery M / W / Th am / F pm Plastic Surgery T / Th pm / F am
Room 19	Special X-rays (Pneumoencephalogram and Carotid Angiogram)

TABLE III

HOSPITAL SERVICES

Original CPHA Divisions	New Functional Divisions	Comments
10 Medicine 14 Communicable 18 Dermatology	Medicine	
32 Neurology		Not Examined
38 Psychiatry		Not Examined
40 General Surgery	Same	Includes Open Heart and Vascular cases
48 Opthalmology 50 ENT 54 Dental	EENT	
58 Orthopedics	Same	
62 Urology	Same	
56 Neurosurgery 60 Plastic Surgery	Neurosurgery and Plastic Surgery	
70 Gynecology	Same	
11 Renal		Not Examined
75 Abortion		Not Examined
76 Obstetric undelivered		Not Examined
77 Obstetric delivered		Not Examined
80 Newborn		Not Examined
89 Stillborn		Not Examined

observe these subdivisions per se.

The reasons for the particular combinations yielding new functional services are as follows. Patients identified by "Medicine", "Communicable", and "Dermatology" all use the same overall bed area, so are all identified by "Medicine". Open heart surgery (which has a separate operating room) and vascular surgery (which does not) are not differentiated in the CPHA services from General Surgery. It would be inconvenient, but perhaps advantageous, to separate them in the future. The EENT subgroups share a common bed area and a common spot on the slate. Furthermore, although theoretically Opthalmology and ENT have individual OR's and different days, in practice there is some intermingling. Neurosurgery and Plastic Surgery share an OR and sometimes, since Plastic Surgery does not have its own, a bed area.

Some services were not considered in the model, for the following reasons.

Neurology could almost be termed "investigative Neurosurgery". Neurology and Neurosurgery do indeed share the same admission form (colour coded for distinct types), a bed area (which is often entirely categorized as for Neurosurgery), and largely the same physicians. In any case, the Neurosurgery and Plastic Surgery service was not implemented in the model, and thus the problem of considering how to include Neurology was not faced.

Psychiatry, which is housed in a separate building, is effectively independent. There is no bed overlap with other areas. If one of the patients requires surgery or a different hospital bed, he is reclassified and recounted.

Since the ordinary admission process will not accommodate the variability of the outset of labour in pregnant women, maternity admissions are handled differently. The case room keeps a pre-natal record on prospective mothers, and each week informs the maternity ward what to expect. The delivery room is separate from the operating rooms. There is very occasionally a bed interchange with Gynecology. If a patient with a history of difficult births, but predictable carrying time, is due to come in, an OR may be booked in advance through the Gynecology slot. Caesarian sections, ligations, and bleeding cases may be sent to an OR on an emergency basis. It would be possible to have the Maternity service in the model as a randomly-occurring exogenous demand on OR usage, but it was felt that this effect was sufficiently small to be excluded safely. As a consequence, there was no need to include nurseries either.

St.Paul's Hospital used to have a Pediatric service, but no longer does. As a result, LOS data was adjusted to compensate for the tendency of young patients (who were included in the original data sample) to have short stays.

For a more extensive patient classification it would have been necessary to examine groups of diagnoses which tend to yield groups of patients who are homogeneous in terms of hospital placement, LOS, length (and other demands) of surgery, and special care patterns. Such an attempt, on the basis of H-ICDA diagnosis and operative groups, was considered. However, this was soon seen to be infeasible in terms of the amount of time it would have demanded from professionals capable of formulating such a classification, and the amount of familiarization it would have demanded of the modeller.

Since the CPHA "hospital service" is generally based on the "primary diagnosis explaining admission", we considered it to be a good basis for a subdivision. In reality, it is not always clear which service a patient should be classified under. An emergency patient may be admitted to the care of two different physicians, and may transfer from one area of the hospital to another during his stay. Such ambiguity was not thought to be frequent or serious.

5.1.2 Hospital Units

There are several special units within St. Paul's Hospital which are defined in terms of the care they offer rather than in terms of a patient's "service" classification.

The Renal Unit, which used to define a service category, now operates on an outpatient basis. It has only seven beds, each of which may be used three times a day. If one of the unit's patients requires admission to the main hospital area overnight, he will be re-classified and counted as admitted to another service. A patient being prepared for a dialysis setup would be classified under General Surgery. For a kidney removal, he would be in Urology. Some minor flaws may be present in the Medical LOS data due to unclear classification prior to and during the Renal Unit's reclassification as outpatient.

As noted on Table II, one or two operating rooms are used for Day Care surgery, along with ten or so beds. This service is also handled on an outpatient basis, and does not overlap with the main hospital's bed or OR use. Not even the PAR (Post-Anaesthetic Recovery room) is used. As with Renal patients, a Day Care patient staying overnight is reclassifed. Of course, the OR Booking Office may need to worry about scheduling a surgeon who is to use both Day Care and other surgery time on a particular day, but this level of detail was not observed in the model. The Day Care surgery process was not included.

The most complex unit in terms of its interactions in the hospital set-up is the Intensive Care Unit / Coronary Care Unit (referred to only as the ICU), which has twenty beds. It receives patients who have had myocardial infarctions and will receive "conservative" non-surgical treatment. It also receives respiratory patients requiring assisted or mechanical ventilation and vigorous physiotherapy. Patients with acute renal failure or unconsciousness due to poison or drug overdose may arrive via the Emergency Unit. Any Medical failure or surgical disaster requiring intensive care may result in a transfer to the ICU. Many of the patients in the ICU come from the Emergency Unit, the next largest number from the PAR (Neurosurgical, thorax, heart, and major vascular cases go to the ICU after 24 hours of monitoring in the PAR), and the rest from the ward catastrophes in the whole hospital. Patients usually return to an appropriate area after stabilizing and before being discharged. As a result, the ICU is responsible for a large number of in-hospital transfers. Originally intended as an entirely Medical unit, the ICU does handle some surgical patients.

A nearby unit which works closely with ICU is the fifteen bed cardiac surgery unit. This is the area to which outside heart patients and in-hospital cardiac arrests who will be "aggressively" treated are admitted before surgery. After surgery they spend 24 hours in the PAR and 2-3 days in the ICU before returning to the cardiac unit until discharge. There is some overlap and interaction in the use of ICU and cardiac beds, but basically the cardiac unit is the open heart surgery bed area.

The activation area is used to start rehabilitation. It has about fifteen beds and processes 30-35 patients per month. Patients being treated here originate about equally from the Medicine, General Surgery, and Orthopedic areas. Most of the patients are sent home or for care, with less than 5% returning to their previous hospital area.

Since the patient classification used was not specific enough to identify patients who would receive care in the areas discussed in this section, they were not considered for inclusion as separate units in the model. However, if indicated by their use, beds from these areas were added to the total number of beds "pooled" for the appropriate services.

5.1.3 Bed Groups

As Table I indicates, a patient desiring admission to most hospital services can request private, semi-private or ward accommodation. Isolation requests such as those for infection require private rooms. The difference in accommodation however, is usually a matter of preference and cost. Of the patients desiring non-ward accommodation, some will wait until it becomes available, others are admitted and transfer when a vacancy appears. If only private accommodation is available, an elective patient who did not specify that type may be called and offered it at the extra cost. As Lew (1966) calculated, type of accommodation is not a significant factor in LOS.

As is indicated in Table IV, some accommodation is intended for males and some for females, as well as some which may be used by either sex. However, much juggling is done among small and large wards to maintain homogeneity by sex. In practice, a patient is seldom refused admission (for very long anyway) due to his or her sex.

It is very difficult to keep track of patient movements in the hospital. No record is kept of location (except perhaps for billing purposes). The main bed board, the patient file, and the ward records show where a particular patient is, but it would be difficult to keep precise records of the path through the hospital for any large number of patients. As a result, there have only been a few small studies of patient transfers done at St. Paul's.

TABLE IV

BEDS BY SEX

Service	M	F	M or F
Gynecology		20	21
EENT	6	12	17
Orthopedics	40	30	
Urology	29	7	7
Neurology & Neurosurgery	6	6	11
General Surgery	33	38	36
Cardiac Unit	4		11

As a result of the considerations mentioned above, the model we developed did not group beds by accommodation or sex. Each service was considered to have a "pool" of beds from which each patient used one.

5.2 Admitting Considerations

The Admitting Office is responsible for placement of patients in the hospital. Medical booking forms and surgical booking forms (once the date of surgery and hence of admission has been determined) are filed there. Emergency patients are also placed by this office. For special care units or teaching areas the resident physician may control the beds, but for most areas, an admitting clerk decides who goes where. Transfers are also co-ordinated by the office, and it is informed of discharges. It maintains the waiting files and the bed board.

5.2.1 Bed Usage

Bed space is the critical factor in St. Paul's Hospital. The primary constraint on scheduling surgery is the number of beds available. Occupancy averages about 93%, and is even higher in mid week. Theoretically about eighteen beds are meant to be reserved for emergency patients, but this is not strictly observed. As a result, patients must sometimes be placed temporarily in TV rooms or alcoves. About 25% of the Medical patients and 15% of the surgical patients are initially admitted to the wrong area. Quite a few are never transferred to the proper area.

In the nursing units described in Table I, it is known that many of the beds may be used for other services. Of the 41 Gynecology beds, about ten are usually filled with non-Gynecology patients. The same holds true for the 43 Urology beds, for which the ten off-service patients are often from General Surgery. Most of the General Surgery misplacements are among the A, B, and C areas. Orthopedic patients may be placed in Neurosurgery beds. ENT patients may go to Orthopedic beds. Though by no means an exhaustive or quantitative list, the preceding statements are suggestions from the Admitting Office of probable variations. Elective patients are seldom admitted to the wrong area. It is the emergency arrivals who require shuffling. The fact that about 45% of total and 75% of Medical admissions are emergent or direct urgent (DU) underlines the magnitude of the problem. When these patients arrive, one cannot expect the available beds to be where one would like them to be.

5.2.2 Sequence of Claims on Beds

Since it is clear that the Admitting Office cannot always offer the right bed, then some pattern in handling claims on beds must be followed. When new staff arrives each morning, it is faced with a number of in-hospital patients who may either require or desire transfer and a number of elective patients desiring admission. As has been indicated, the OR Booking Office schedules patients for surgery, then sends the Admitting Office a copy of the admission booking form with the date of desired admission stamped on it, to be filed and arranged there. The Admitting Office tries not to disrupt this process. Failure to admit a surgical case when scheduled is a "No Bed" situation, to be discussed in the next section. Thus the major concern of the Admitting Office is in the use of Medical beds. An approximate sequential pattern which the Admitting Office uses is as follows.

Late overnight admissions to the emergency unit must be placed in the hospital. Also, patients who had to be placed in a Medical area "closed teaching bed" (to be explained in Section 5.2.5) against the will of the resident should be moved. Next, patients who had to be placed in alcoves or TV rooms on previous shifts should be moved to proper areas. The ICU should be emptied of patients no longer requiring its facilities, particularly if it is a period of high demand for intensive care. For those patients still in the five "extension beds" of the PAR (for up to 24 hours of post-operative monitoring) placement should be arranged elsewhere. Medical patients who have been found to need surgery should be transferred to an appropriate surgical area. After these, an attempt should be made to move any other patients who are in the wrong area, particularly Medical emergency patients who had to be put in a surgical area. After all these moves, and after some allowance for the day's emergencies, if there are any beds left then schedulable admissions may be considered.

5.2.3 "No Bed" Situations

The OR Booking Office schedules each patient for surgery and, indicating the necessary admission date according to the pre-operative stay specified by the admitting physician, sends a copy of the admission booking form to the Admitting Office well in advance. If when the admission date arrives, the Admitting Office cannot find a bed to put the patient in, it is referred to as a "No Bed" situation.

The OR Booking Office must inform the surgeon, and try to reschedule his patient within two weeks (usually it is attempted one week later). They must try to fill the vacant spot on the upcoming slate. The patient must be informed of the change.

For obvious reasons, this is an undesirable situation. It upsets the patient, who probably had to arrange for time off from his or her job, and perhaps for a babysitter. Such inconvenience, although inadvertent, reflects badly on the hospital. Repeated difficulty of this sort at one hospital will cause a physician to favour another. Also, it disrupts the slate.

Nevertheless, "No Bed" situations happen quite often. Most of my data is from 1974 when, in 250 operating days, only 160 were free of "No Beds". There was an average of 39 "No Bed" cases per month, with up to twenty on a single day. These cancellations occur in all surgical services. There has been some improvement since 1974 (the 1976 average was 31 per month), but it is still a real concern to administration.

5.2.4 Patient Admission Diagnostic Categories

All five patient admission categories (based on diagnosis) were considered. Three of these are schedulable and are indicated by the physician on the admission booking form which is submitted for the patient. They are urgent, semi-urgent and elective. There are also the emergency and direct urgent categories, which require immediate attention.

Each of the categories except DU is broadly defined by hospital policy. The excerpts which follow are from Appendix I of a directive to physicians in May 1973. An emergency condition is so severe that "death, severe pain, chronic illness or permanent disability may result if hospital treatment is not given". Such patients should be admitted within 24 hours. An urgent condition is "one of moderate severity which may develop into a state of emergency or the patient may suffer serious deterioration if hospital treatment is delayed for more than a maximum of fourteen days". A semi-urgent admission need not be within two weeks, but should not be over two months. Elective patients desire admission, but "a delay should not directly threaten life or health".

In practice a patient is only classified to be an emergency case if he is admitted via the emergency department. There is a further classification used, called "direct urgent", which probably includes some patients who could be classified as emergent and some as urgent. These are patients for whom, when the physician sees them at his office or elsewhere, he decides they should be admitted very quickly. He contacts the Admitting Office immediately to see if there is any room. If so, the patient goes directly to the Admitting Office and is admitted to the hospital. If there is no room in the immediately foreseeable future, the physician may fill out an admission booking form indicating that the patient is urgent and submit it - with some added emphasis - to the Admitting Office, or he may send the patient to the emergency unit.

When beds are full, but the physician feels strongly enough that he sends his patient to the emergency unit, hospital staff terms it a "backdoor admission." It is classified as an emergency and is not differentiated in any records. Unfortunately, the slow movement of the waiting queue, particularly for Medicine, often results in such tactics (a device which clearly perpetuates itself).

Of the scheduled admissions, theoretically all urgent patients are handled first, than all semi-urgents, then the electives. In practice, there is a fair amount of judgment in priority adherence. The physician may change the classification, or by communication with the admitting clerks may influence his patient's priority. Furthermore, despite the description given by the hospital, the use of these diagnostic categories differs among physicians. (See also the comments in Section 12.1.)

5.2.5 Control of Medical Beds

St. Paul's is a teaching hospital. As a result, the Admitting Office does not have complete freedom in assigning beds to patients. For instructional purposes, there are some beds over which the resident has control.

In nursing unit 2 South B, all of the beds are "closed teaching beds". This means that the resident has almost complete control. In late evening or at night, the Admitting Office may place emergency patients there before filling alcoves. However, if these patients are not transferred out the next day, the resident in charge will probably inform the Admitting Office of his displeasure.

There are eighteen semi-closed teaching beds in 2 South A and twenty more in 2 North. If these are required for ICU or emergency patients, the Admitting Office may inform the resident responsible for the beds, and use them.

The teaching resident regularly looks over the filed admission forms and picks out "interesting" ones. Active staff members also make arrangements with the residents to admit their patients to teaching beds. In fact, one of the few ways for an elective patient to enter a St. Paul's Medical bed easily is to be chosen for a teaching bed.

Hospital guidelines - given the high demand for beds - suggest that if more than 20% of the patients in teaching beds are not those chosen by the resident, the Admitting Office should transfer the wrong ones out. Still, residents claim that there are sometimes 25% or 50% "non-teaching" patients in their beds.

Due to the complexity of gathering data on who gets teaching beds, the variation of LOS between teaching and non-teaching patients, and the lack of a consistant pattern in using the beds, teaching beds have not been differentiated in the model. All Medical beds are used identically.

5.2.6 Surgical Non-Operative Admissions

Not all of the patients who are scheduled to enter a surgical area bed are operated on. Sometimes a physician wants to admit a patient for investigation before deciding whether surgery is advisable. The booking forms for pre-investigative surgery patients go to the Admitting Office (rather than the OR Booking Office). Such patients are admitted on weekdays, since X-ray and lab facilities are only available on an emergency basis on the weekend.

Since it is not clear how many patients of this type there are (it appears that there are few) nor how many of these are later operated on (these would be included in in-hospital demands anyway), the model did not differentiate these patients.

It should also be noted that a number of other surgical patients (many from the Emergency Unit) are never operated on. Patients with bleeding ulcers or traumas that stabilize Orthopedic "bed rest" patients, patients for Neurosurgical tests and Urology patients who pass their stones are of this type.

5.2.7 General

St. Paul's has a large referral program, for which patient admission is handled through a local consultant. Some preference may be given to out-of-town patients. Often the physician requests a particular admission day.

There is no limit to the number of forms which a physician may submit. A limit of five had been recommended in order that the physician would identify his highest-priority patients.

The Admitting Office attempts to ensure that a patient is not cancelled a second time due to "No Bed".

There is a number of staff categories: Honorary, Visiting Consultant, Senior Active, Active, Associate, Courtesy, Non-Active Courtesy, Clinical Fellows, Dental, and Scientific and Research. These are described in "Medical Staff By-Laws". For admission priority, staff category is only considered "other things being equal" and hence is seldom a factor (most admissions are by active staff anyway). As a result, staff category was not included in the model.

5.3 Surgical Scheduling Considerations

For the past two years, St. Paul's Hospital has had a separate OR Booking Office. Admission booking forms for surgical patients (non-investigative) are sent there from the physician. The patient is scheduled for surgery and the necessary admission date is indicated on one copy of the form, which is then taken to the Admitting Office which handles the admission. Although it is simple to say "scheduled for surgery", there are many factors to be considered. These are now discussed.

5.3.1 Operating Rooms

Table II, with its daily slate subdivision, also indicates how the various operating rooms are normally used - or rather were as of July 1976. In August, Orthopedics and Gynecology switched rooms. There are actually nineteen rooms, but not all are needed and, staff claim, none is really large enough.

Table V gives approximate sizes of the rooms, and comments on their use.

5.3.2 Use of Information on the Admitting Forms

There are several pieces of information on the admission booking form which are useful in scheduling. The first, of course, concerns whether In-Patient or Day Care surgery (the model does not consider the latter) is desired. The type of admission (diagnostic category) and date preferred are used to determine roughly when to try to fit the patient in. The type of case may cause it to use one of five overnight PAR "extension beds" or certain special equipment, but neither of these constraints was considered critical enough to be incorporated in the model. Also, the physician is noted, because each has an

TABLE V

OPERATING ROOMS

Room	Size	Usual Use	Use Comments
1	Large	Orthopedics	Formerly Gynecology Can be Gen'l Surgery or almost anything - even double setups
2	Medium	General Surgery	Use by Gen'l Surgery A, B, or C determined by case type & day
3	Medium	Urology	Seldom 3 and 4 both in use Often free for emergencies
4	Medium	Urology (Cystoscopy)	Only for cystoscopy Does most of Urology cases
5	Medium	Day Care (Cystoscopy)	Only for Cystoscopy Usually reserved for Day Care
6	Tiny	Storage	
7	Medium	Day Care	Exclusively Day Care
8	Small }	} ENT }	} Small lights In a pinch, could do something else - of the four, 10 is best
9	Small }	}	}
10	Small }	}	}
11	Small }	} Opthalmology }	}
12	Large	Open Heart Vascular	One OH per day, then vascular If spare time, can do anything
13	Medium	Pathology Lab	
14	Large	General Surgery Vascular	Use by Gen'l Surgery A, B, or C determined by case type & day
15	Small	Cast Room	
16	Medium	Gynecology	Formerly Orthopedics
17	Small	General Surgery	Use by Gen'l Surgery A, B, or C determined by case type & day
18	Medium	Neurosurgery & Plastic Surgery	Cramped, but possible for other
19	Large	X-ray	Special X-ray equipment only

upper limit on the number of beds he may book per day and, if he is not on active staff, his request may be of lower priority. The date of receipt is stamped on the form. The number of days for pre-operative stay are noted, with the reason. For example, if X-rays are needed, the surgery will not be scheduled for Monday, since X-rays are not done over the weekend.

5.3.3 Pre-Operative Stay

The physician always indicates the pre-operative stay required for his patient. For 60%-70% of the patients it is only the night before. Patients needing blood are usually in the hospital a full day before surgery, those requiring X-rays or tests probably two days. Heart, vascular and bowel patients need about three days preparation. Obese patients are the most time-consuming, needing five or more days before surgery.

5.3.4 Block Booking

The OR Booking Office cannot choose to schedule a patient on just any day which fits the other constraints. Most surgical services at St. Paul's are "block booked". Rooms are blocked out so that each day certain physicians are given their turn. One major advantage of this system concerns a surgeon's private practice. If he knows that he may expect to operate on, say, Wednesday mornings, he can plan his office hours well in advance, with that provision.

Block booking also enables a surgeon to regulate his demand and expectations of the surgical booking. Depending on how long his operations are likely to take, he knows how many forms to submit and, if he cares to, he may probably predict which day a particular patient will be operated on. For that matter, the physician may request that his patient be slated on a particular day for which he is booked. However, there is a limit to the physician's control of the block. In particular, if he has not filed enough request forms to fill his block eight days in advance, his block is thrown open for urgent patients of other surgeons, and for in-hospital requests.

Neurosurgery and Plastic Surgery are not block booked. General Surgery is blocked by "service" category A, B, and C only, not by physician.

5.3.5 Service Characteristics

Since General Surgery is blocked by service only, some attempt is made to balance by surgeon as well. Generally one patient for each active staff surgeon is chosen at a time. Choice is guided by the date of receipt of the form, and each choice is placed on the slate eight days in advance. There is no General Surgery backlog.

Vascular surgery has the equivalent of two days of blocked time per week, and is always booked up. The open heart spots are usually filled for a month ahead.

The Neurosurgery and Plastic Surgery slate is also prepared eight days in advance, rather than being developed as forms arrive.

Orthopedics and Gynecology spots are often not used by the blocked surgeon, but are filled up after being opened to others of the service.

Urology is not thrown open very often. It has no backlog.

EENT is often booked four to six weeks ahead.

5.3.6 Limitations on Scheduling

The main limit on scheduling for surgery is the number of beds. If patients with a schedulable admission category are booked up to the bed limits, there is always room left for in-patients. Approximate bed limits by service appear on Table VI.

The recovery room can only take five "extensions" (overnight patients). These beds are monitored closely, and are required for such cases as heart operations, pacemakers, tumors, craniotomies, chest operations and perineals.

There are also some equipment and instrument constraints. The laparoscope may be used for one diagnostic and one operative procedure per day. The mediastinoscope and arthroscope may be used once per day. The image intensifier can only be used on one procedure at a time. Although the Booking Office must consider these constraints, they are not critical (and patients are not classified so distinctly as to be identified as needing them), so the model does not consider such limits.

TABLE VI

BED LIMIT GUIDELINES

Service	per day	per week
Gynecology	4	19
Urology	5	
ENT	6	
Opthalmology	6	
Orthopedics	4	17
Neurosurgery	2	} 19
Plastic Surgery	3	}
General Surgery		
A 2 rooms M / W ; 1 F }		
B 1 room M / Tu ; 3 Th }	9	
C 2 rooms Tu / F ; 1 W }		

TABLE VII

IN-HOSPITAL DEMANDS FOR SURGERY

Service	Number
General Surgery	4-6 / day
Vascular	2 / week
Open Heart	1 / week
Urology	1 / day
Orthopedics	1 / (2 days)
Neurosurgery	2 / week
Plastic Surgery	1 / week
Gynecology	1 / week
EENT	1 / (2 weeks)

The major nature of certain cases requires that they be done "first thing" (at 8 am). At that time any "total hip" operations start in room 1, craniotomies in room 18 and abdominal perineals in room 14.

5.3.7 Considerations of Auxiliary Staff

In general, this model assumes that the hospital will employ whatever levels of auxilary staff (nurses, anaesthetists, and others) that the level of demand by physicians and patients warrants. They are never expressly included as entities in the model. However, it is worth noting the effect of auxiliary staff on turnaround time, adherence to the day's slate, and OR availability after 3:30 pm.

Turnaround time (between operations in a particular theatre) depends on several factors - which are influenced by the preceding and following operations. Does the anaesthetist need to stabilize the last patient? Is there a housekeeper available immediately to wash up - or are they all busy elsewhere? How quickly can the nursing staff prepare instruments for the next operation? In booking time, the OR Booking Office allows one quarter hour between minor operations, one half hour between major ones, and more for vascular or Neurosurgical cases. In reality, major or minor operations can require anywhere from about five to forty minutes turnaround. The model, not operating on a small time scale anyway, only uses a fixed turnaround time.

There are two charge nurses and a head nurse who, in addition to monitoring and evaluating nursing staff, may also place extra nurses or step in themselves in order to help the slate run as timed. They make sure that all of the nursing staff members get breaks. The head nurse can arrange for extra nurses if cases get behind. Up to two "stagger nurses" can be called to help with late cases and relief.

It is preferred to have two nurses per room (as well as one nurses' aid). "Open heart" gets three nurses. Normally cases run from 8:00 am to 3:30 pm. Besides the regular nurses for this time, there are four afternoon nurses (one from 3 to 11 and three from 3:30 to 11:30). Two night shift nurses come on, so that after 11:30 pm, one emergency room can be used as long as necessary.

It is worth noting that no patient is ever removed from the day's slate, whatever the length of previous operations.

5.3.8 In-Hospital Demands

One of the major complicating factors in scheduling the slate is that physicians may submit requests for surgery for their patients already in the hospital. Some of these have already had one operation. For General Surgery, Neurosurgery or Plastic Surgery, such requests usually wait for the proper physician's next day of surgery. Requests from the other services are added to the slate as soon as possible. If an in-patient happens to refuse a time that is offered, he goes to the end of the list again.

Approximate numbers of demands from the various services appear on Table VII.

In-hospital requests are placed in spots left unclaimed by physicians, or in time left after outpatients were limited due to bed space.

5.3.9 Handling of Emergencies

When a physician comes to the operating floor requesting surgery for his in-patient, the main question is "How urgent is it?". If possible, the request will be deferred to the next day and scheduled on the slate. For those which should be handled the same day, but can wait, they are organized on a first-come first-served basis at the end of the slate. Any change in order would be worked out on a physician-to-physician basis.

For emergencies which should be handled promptly, such as haemorrhaging in the PAR, there is always a place to go. (There are always several rooms not in use.) The largest available room is always chosen. The anaesthetist on call and nursing staff are summoned. Another option is to "break the slate" of some room, hence making it late. If the patient is stable, the case is inserted when a staffed room becomes free.

Since the model only operates on a one-day time unit, it is not necessary to differentiate among emergency handling methods. The model's output merely indicates the total time used each day for emergencies - which is, in fact, recorded by hospital staff.

5.3.10 Timing of Slate Construction

The OR Booking Office has a six-week visual file on which booking forms are inserted. As these forms arrive, they are added to the file, depending on considerations mentioned previously. The physician has usually estimated operating time to a multiple of one quarter hour. The booking nurse adjusts the time according to that physician's tendency toward accuracy or inaccuracy in estimation. Keeping within time and room limits, she fills in the slates for each day. Bookings are never scheduled to run past 3:30 pm.

Once the operating day is eight days away, any open spots on the slate may be filled with urgent or in-hospital demands. Extra space may go to non-active staff. Real urgents (those the physician would clearly like to have admitted quickly) are usually not kept waiting over a week. A copy of the slate is prepared in the afternoon two days ahead. The next morning, physicians and the Admitting Office are checked to make sure everything is OK. Cancellations, "No Beds" and in-patients still cause changes. Then about noon the final copy is made. This will control OR usage the following day.

5.3.11 General

There are a few other factors which affect OR scheduling. Besides physicians' office hours (which the Booking Office knows), their time away for conferences and holidays must be observed. Some rooms are occasionally unavailable due to maintenance.

There are also some unexpected sources of problems. For example, a patient may be slated, and admitted. Then, after talking to other patients around him, he may refuse to sign the surgery consent form. Such things do not happen very often and are not included in the model.

CHAPTER 6 MAJOR FLOW PATTERNS

6.1 Purpose and Form

The extended flowchart system presented in this chapter visually describes the model framework and identifies all relevant interactions within the system. During the development of the model these charts contributed to and were refined by the processes of clarifying relevant model features and determining data requirements. The final form of the flowcharts includes modifications and assumptions which had to be made to deal with the unavailability of data on some aspects of the system.

In system flowcharts, two streams are often identified, information flow and physical flow. In the description used here, the "physical unit" of interest is the patient. These diagrams actually describe information flow relative to the patients. For example, when an admission request arrives at the hospital, it arrives as a form, as information, usually unaccompanied by a patient. When a patient is slated for surgery, again there is no actual patient at hand, but the information is vitally important to this model. Of course, once the patient arrives at the hospital, the physical and information flows often coincide. Nevertheless, it will probably be helpful to conceive of the flows here as information about patients.

The format of this description tends to follow the System Book outline (Grams 1972). The complexity of the model calls for an overview flowchart which serves as a graphic index to subsequent flowcharts, and several system flowcharts depicting the details of the subsystems. Each flowchart symbol has a number in parentheses associated with it which tags an operations statement giving any necessary or useful explanation.

6.2 Overview Flowchart

This first flowchart sets out, in general terms, the patient information flows of the model.

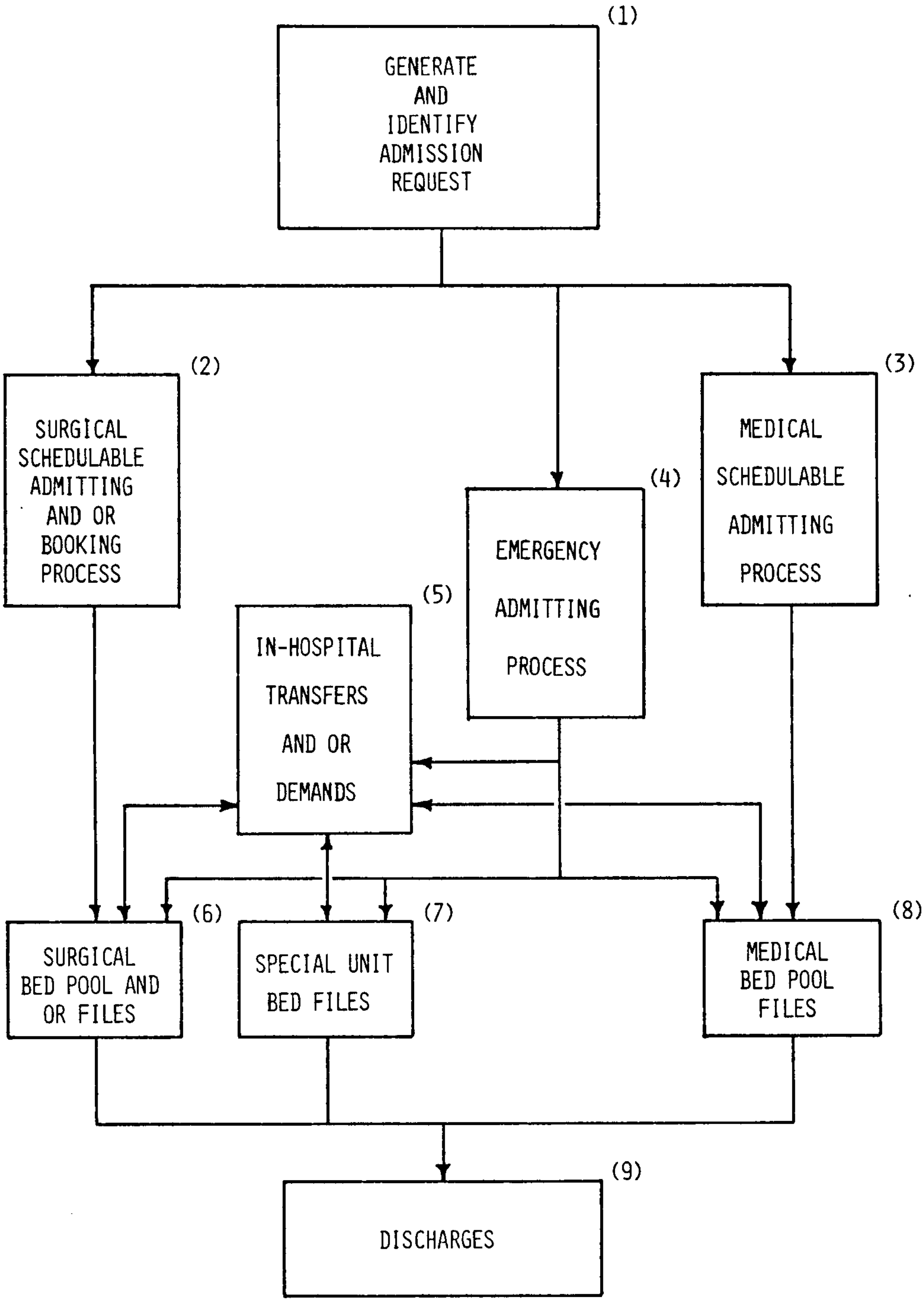

Fig. 6.1 Admission and OR scheduling information flowchart (I)

Operations Statements (I)

1. From the patient pool, requests for admission arrive as booking forms from Medical physicians or surgical specialists with admitting privileges, or through emergency (or DU) arrivals at the hospital. See flowchart II A.

2. Schedulable (non-immediate) surgical patients' requests undergo coordinated OR booking and admission procedures. See flowchart III A.

3. Schedulable Medical patients' requests are processed for admission. See flowchart IV A.

4. Emergency and DU patients requiring admission are immediately served. See flowchart V A.

5. In-hospital demands result in some OR use and bed transfers between pools identified here. See flowchart VI A.

6. See flowchart III A.

7. ICU and Cardiac units. See flowchart VI A.

8. See flowchart IV A.

9. Patients no longer occupying a bed return to the patient pool (or are deceased). See flowchart IV A.

6.3 Detail Flowcharts

The flowcharts and operations statements which follow describe in detail the processes indicated on the overview chart.

The numbers in square brackets at the end of each comment are cross-references to any appropriate data items of Table IX (Data and Information Used).

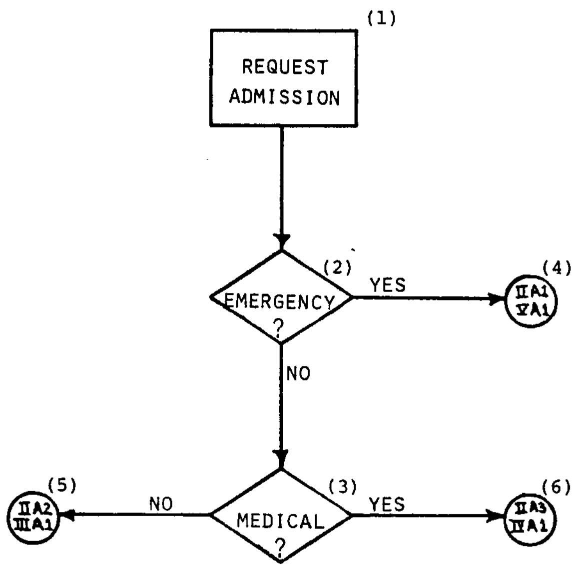

Fig. 6.2 Admission requests flowchart (IIA)

Operations Statements (II A)

1. Patient "generation" is by service, and is proportional to the number of physicians active in that service.

Services:

- Medicine
- General Surgery
  - includes vascular
  - may include open heart
- Eye, Ear, Nose and Throat (EENT)
- Orthopedics
- Urology
- Gynecology
- Neurosurgery }
- } the model combines these
- Plastic Surgery }

Each patient admission request is assigned:

- service
- admission diagnostic category:
  - Elective, Semi-Urgent, Urgent,
  - Direct Urgent, Emergent
- physician
- age, sex
- LOS
- any requested admission date
- perhaps ... transfer timing and routing

for those patients to be operated on:

- pre-operative LOS

length of surgery

[4,5,6,7,8,9,10,11,12,13]

2. The immediate (DU,Emergent) and schedulable (El,SU,U) categories are handled separately [6]

3. The schedulable patients are divided between Medical and surgical services [4]

4. To the start of emergency unit processing.

5. To the start of surgical services processing.

6. To the start of Medical services processing.

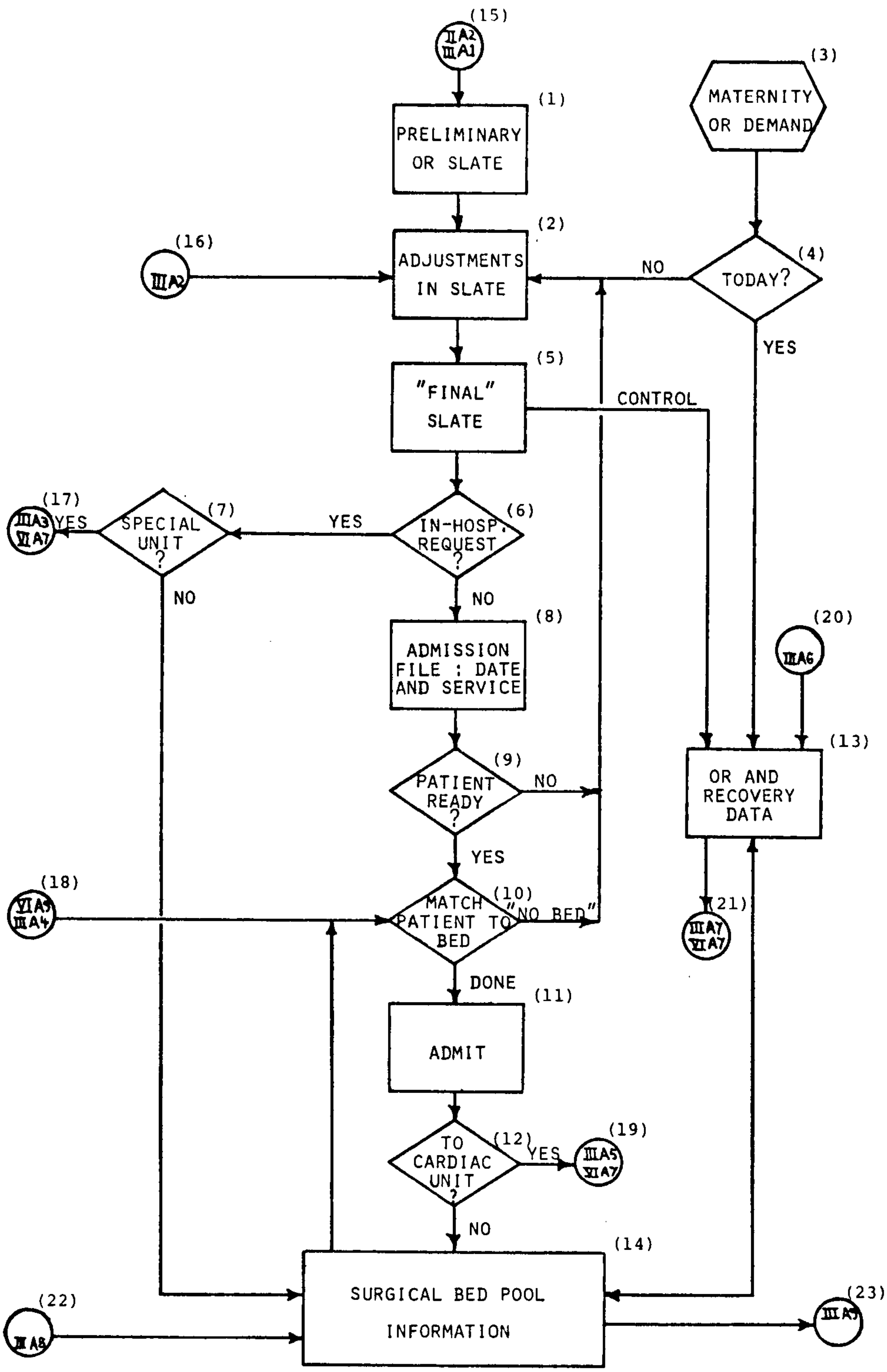

Fig. 6.3 Surgical services and operating rooms flowchart (IIIA)

Operations Statements (III A)

1. In the OR Booking Office, the request forms are filed in a tentative location on the six-week visual file, or in the file box to go there. Requested surgery date is considered, as well as patient admission diagnostic category. Surgery is generally block booked by physician (except for General Surgery which is booked by service A, B, or C, and Neurosurgery / Plastic Surgery which is not block booked). There are bed limits for each service per day and per week. There are time constraints (a maximum of seven hours per theatre). At this preliminary stage, some flexibility is left. [5,6,12,13,14,15,16,17]

2. Surgical emergency admissions cause some slate modifications. About one week ahead of scheduled surgery, spaces left in the slate begin to be filled by backlog, in-hospital and urgent requests. Postponers and "No Bed" patients must be re-booked. Patients who are made to wait a long time may cancel. [3,24]

3. The Maternity service may be treated as an exogenous request on OR time, with separate beds. [Not implemented]

4. Is the demand for today (on an emergency basis) or is it schedulable? [Not implemented]

5. "Final" here implies that a definite surgery day has been determined - so the Admitting Office may be notified. Although it may be known well ahead of time, this operation is expected to appear on the final working copy of the slate wich is produced one day before surgery and controls OR usage.

6. If the request was in-hospital, the patient need not be admitted. [24]

7. Is this in-hospital patient in a special unit or a surgical area?

8. Once the day of surgery has been determined, the pre-operative LOS assigned by the physician is used to specify the admission date. This information is then filed in the Admitting Office. [10]

9. The patient may postpone. [Not Implemented]

10. If there is no appropriate space for a scheduled admission, it is a "No Bed" situation.

11. The patient enters a hospital bed. [20,21,23,24]

12. Is the admission to a regular surgical bed or to a cardiac bed?

13. A record is kept of the total number of scheduled procedures per room and of the total daily operating time for both scheduled and emergency operations. Emergencies (those procedures which cannot be planned for a day in advance) come from emergency admissions and in-hospital requests. They may be handled: (i) in a spare room; (ii) in the first available room - which is already staffed with nurses and an anaesthetist; (iii) in a basically First-In, First-Out (FIFO) order at the end of the slate (variations in the sequence are arranged on a physician-to-physician basis). At the completion of the scheduled slate (especially after 3:30) one or a maximum of two theatres may be kept open as long as necessary. [11,17,23]

14. Surgical bed pool information is updated by admissions,

transfers and discharges. In-hospital transfers and OR demands can develop from here. [22,23,24]

15. From surgical service admission requests.

16. From surgical emergency admissions V A6 and from in-hospital demands VI A6, at least one day ahead.

17. An operation for a patient in a special unit must be noted.

18. The bed which matches may be in a special unit.

19. Open heart patients are admitted to cardiac unit beds.

20. From surgical emergency admissions V A5 and from in-hospital demands VI A5 which require surgery today. Also, from the status of special unit patients who are to be operated on VI A9.

21. To update the status of special unit patients who have been operated on.

22. From Medical patients taking a surgical bed V A4, emergency surgical admissions V A7 and in-hospital transfers to surgical beds VI A8.

23. To discharges IV A4, in-hospital transfers from surgery VI A1, bed information for transfers VI A2, and in-hospital OR demands VI A4.

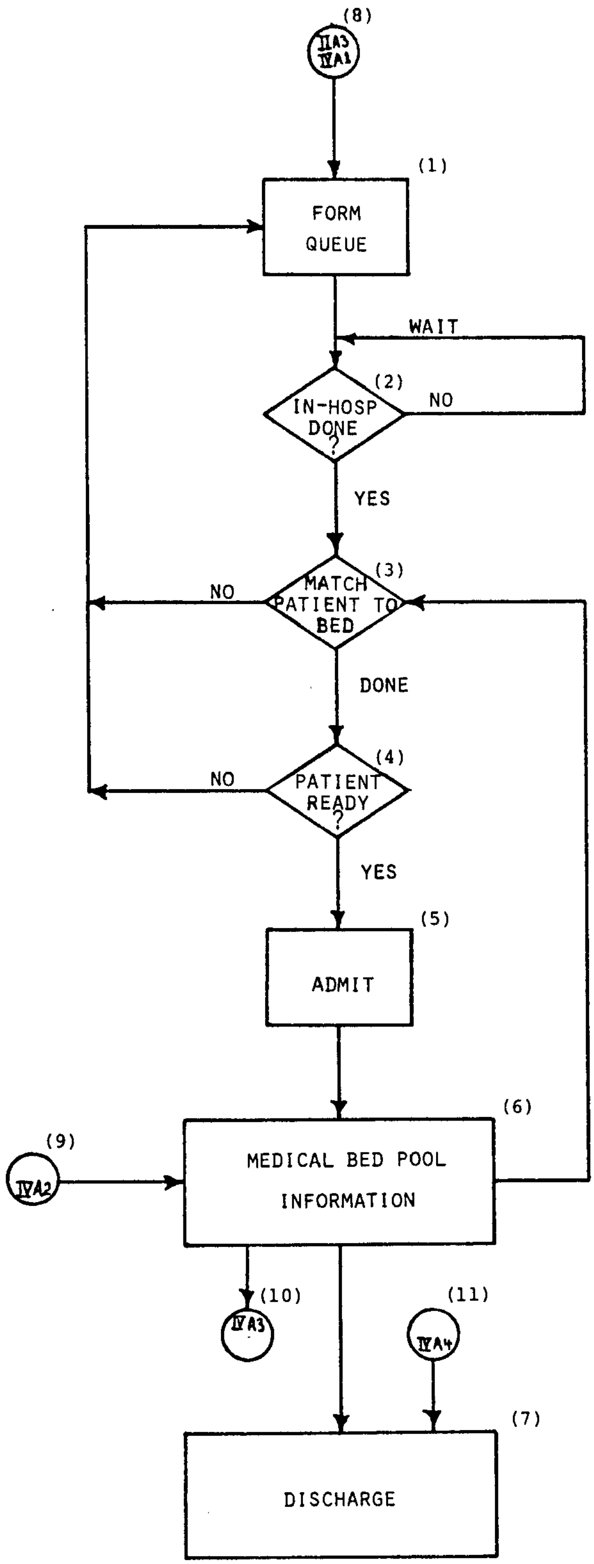

Fig. 6.4 Medical service flowchart (IVA)

Operations Statements (IV A)

Note: Scheduled surgical investigative and non-operative patients follow a similar route, but to a surgical bed.

1. A queue forms, ordered by patient admission diagnostic category and length of wait. The staff level of the physician and whether or not the patient is out-of-town may also be factors. In practice, the queue is almost mental - forms are actually filed with the date of receipt stamped on them, in order of the physicians' last names. Pressure from the physician is a a real but unprogrammable factor. [6]

2. Each morning, in-hospital transfers must be processed before considering schedulable admissions. [1]

3. The admitting clerks attempt to find an appropriate bed. [19]

4. The patient may postpone. [Not Implemented]

5. The patient enters a hospital bed. [23,24]

6. Medical bed pool information is updated by admissions, transfers, and discharges.

7. The patient no longer occupies a hospital bed.

8. From Medical service admission requests.

9. From emergency Medical admissions V A3 and transfers to the Medical area VI A3.

10. To in-hospital transfers from the Medical area VI A1 and bed information for transfers VI A2.

11. From surgical discharges III A9 and special unit discharges VI A9.

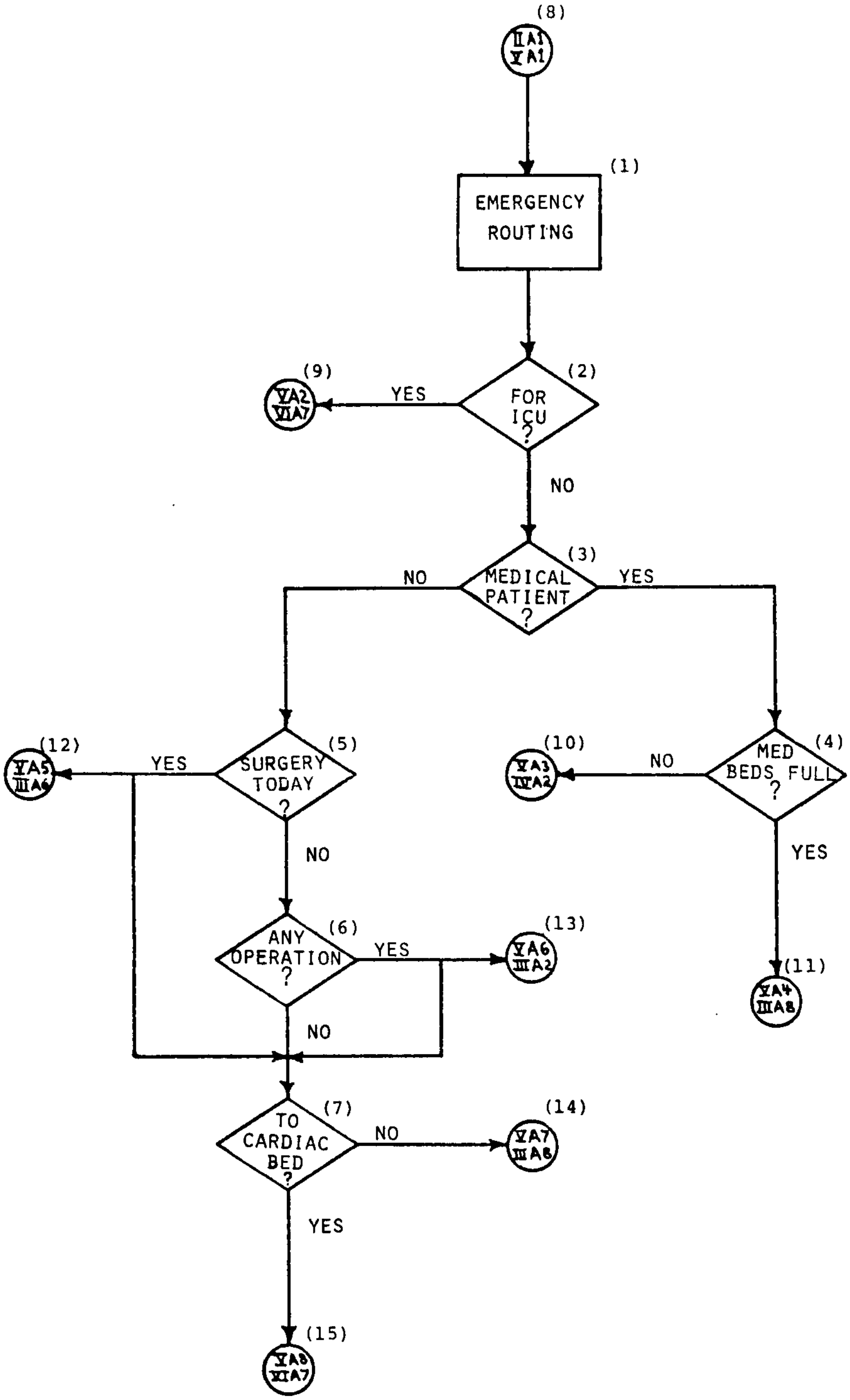

Fig. 6.5 Emergency Unit flowchart (VA)

Operations Statements (V A)

1. This overall process is the routing of emergency patients. Patients included are either emergencies or are "direct urgent" patients from the physician's office who are either critical or, in his opinion, need to circumvent the slow admission queue. It is safe to assume that the Emergency Unit's bed capacity is sufficient - old beds are available in storage if needed. [2,6]

2. Does the patient require close enough monitoring and / or the special care to be in the Intensive (and Coronary) Care Unit? [Not implemented].

3. Is the patient classified as Medical or surgical? [4]

4. If Medical beds are full (including semi-closed, perhaps closed, and some "overflow" beds) the patient may occupy a surgical bed. These patients probably cause in-hospital transfers soon. The semi-closed, closed, and overflow beds used at this point will probably cause transfers soon. [18,20,21,22]

5. Is surgery needed immediately? [23]

6. Does the patient in fact require any operations, or only the care provided in a surgical area? [23,24]

7. Is this a cardiac emergency or one of another service? [4]

8. From emergent admission requests.

9. To the ICU. (Perhaps a transfer should be arranged.)

10. To a Medical bed. (Some will cause transfers.)

11. A Medical patient is placed in a surgical bed, ... which probably causes a transfer.

12. To modify OR data for today.

13. Surgery is required later, so the slate must be modified.

14. To a surgical bed.

15. To a cardiac unit bed.

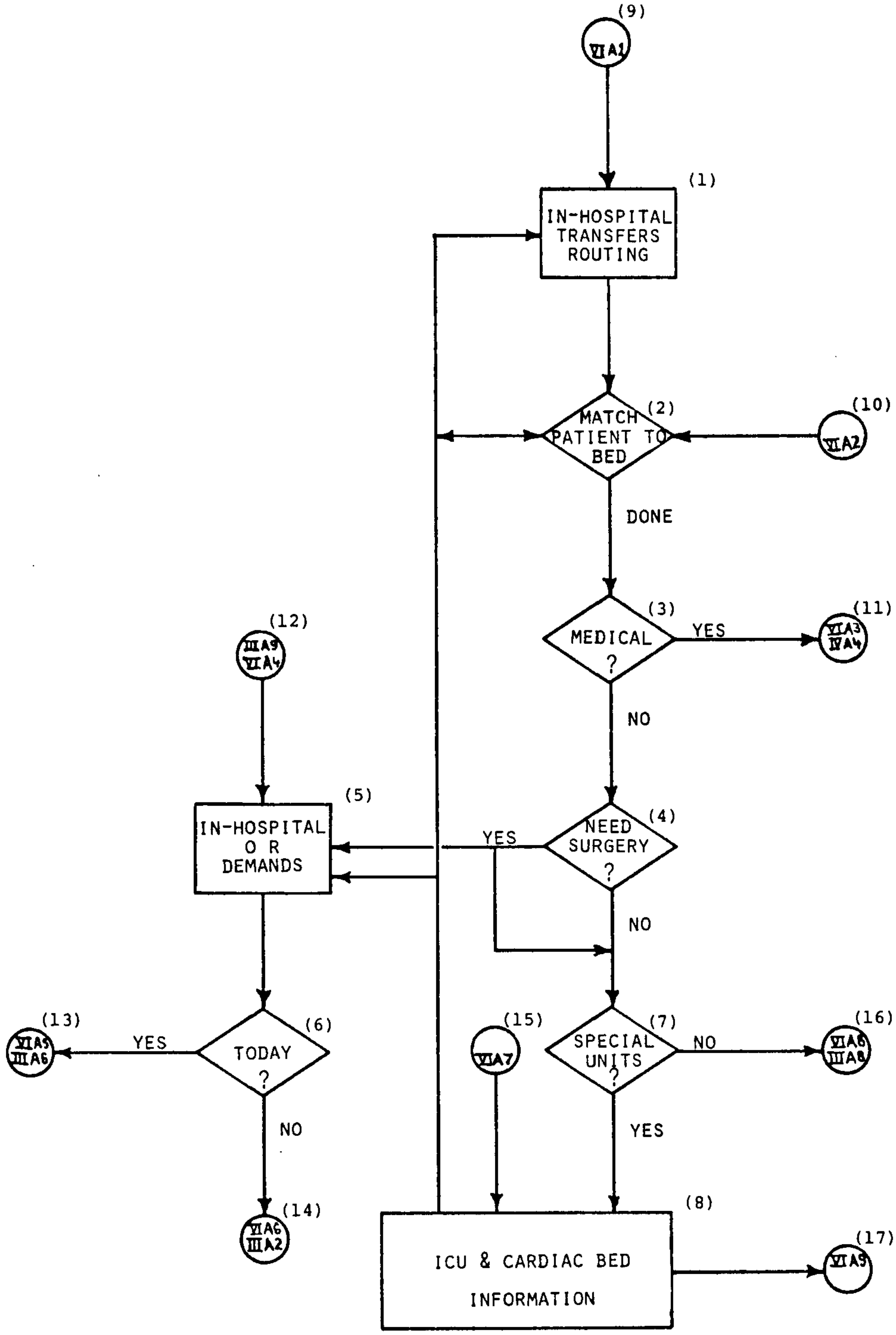

Fig. 6.6 In-hospital variations flowchart (VIA)

Operations Statements (VI A)

1. The process which follows is the routing of in-hospital transfers.

2. The admitting clerk attempts to match the patient to the appropriate bed, which may be anywhere. If there is such a shortage of beds that this cannot be done yet, it will be done later. If matched, the patient must be removed from his former location to the new one.

3. To a Medical bed? (the bed might otherwise be surgical or special) [4]

4. A patient at this point may need a special or surgical care unit although not requiring any operation, or may be returning to a surgical bed from a special unit. These cases would not imply a need for surgery.

5. Demands may come from surgical or cardiac patients who have already had one operation or who suffer some "ward catastrophe" (in which case a bed transfer may not be additionally implied), or from investigative, Medical, or ICU patients found to require surgery.

6. For today or not ... see III A note 13. [23,24]

7. To a special unit bed or a surgical area bed? [Not implemented]

8. "Special units" (ICU and cardiac unit) bed information is updated by admissions to the cardiac unit, and a considerable amount of transferring and discharging. [Not implemented]

9. From Medical transfers IV A3 and surgical transfers III A9.

10. From Medical bed information IV A3 and surgical bed information III A9.

11. To a Medical bed.

12. From surgical unit OR demands.

13. To today's OR data.

14. To modify the slate.

15. From slate-modifying special unit requests III A3, scheduled admissions to the cardiac unit III A5, updating of special unit patients by today's OR run III A7, emergency admissions needing ICU monitoring and care V A2, and emergency cardiac admissions V A8.

16. To a surgical bed.

17. From cardiac bed information to the surgical admissions match III A4, patients to today's OR data III A6, and discharges IV A4.

CHAPTER 7 THE DATA AND INFORMATION USE

The unavailability of data is a prime constraint in the definition of the model and in the determination of the depth of the study. In this work, a variety of data sources was utilized: a magnetic data tape of patient census data, copies of completed surgical slates, emergency admissions forms, Medical and surgical admission booking forms in the course of being processed, as well as the 1976 Admitting Office report (see Appendix 2.1) and, to some extent, a patient transfer study (Scroggs, 1970).

7.1 Description of Data-Sets

The description of the data gathered, and their sources, will serve to clarify the scope of this study and to assist any future data collection efforts. Defined according to their sources, the four data-sets described below were the most important for this work.

7.1.1 Waiting Lists

As it has been mentioned, surgical admission booking forms are received by the OR Booking Office and, usually, stamped with the date of receipt. Once the patient is scheduled for surgery, another copy of the form is sent to the Admitting Office.

Medical forms and pre-investigative surgery forms also go to the Admitting Office. In order to gather data on waiting times for admission to a bed, it is necessary to observe the appearance (or at least presence) and disappearance of these forms. The hospital keeps no records of waits! The best way to observe these data is to record and follow all forms on file over a long period of consecutive days. Unfortunately, it is not always convenient to the hospital staff to have someone collecting data from these forms daily. (A suggestion in that regard may be found in Section 11.3.) Because of this difficulty, the data gathered here are sparse. One part serves to supplement other data (age, sex, arrival rates), another part serves to validate waiting times (output), and yet another part is the only source for certain parameters (pre-operative LOS, diagnostic category).

The data items available from observing the admission booking forms are listed and their use commented on, in Table VIII.

7.1.2 Operations

One copy of the final slate is kept in the OR Booking Office after use. To this copy, the duration of scheduled operations, and the presence and duration of all emergency operations have been added. The slates from 1974 were used because patient LOS data for 1974 were conveniently available.

Since length of surgery was the primary variable of interest, a stratified random sample was collected. The days of

TABLE VIII

DATA COLLECTION GROUPS

Data Group	Item	Use
WAITING	Date form received	Potential use in day-of-the-week distribution
	Date of admission	Rate of schedulable admissions Waiting time validation Potential use in day-of-the-week distribution
	Cancellations	Self-explanatory
	Postponements	"
	"No Beds"	"
	Service	Schedulable patients per service
	Physician	Patient volume per physician Booking pattern
	Pre-operative LOS	Service's distribution
	Age	" "
	Sex	" "
	Diagnostic category	" "
	Date requested	Proportion for service Pattern of use
	Teaching bed?	Potential use for proportion
	Accomodation	" " " "

This group could also be used to show variations made in the slate and placement of patients as per date requested, diagnostic category, teaching bed, accomodation, sex, and service.

Data Group	Item	Use
OPERATIONS	Number per room	Limit Distribution, for validation
	Booker's time	Length of surgery distribution
	Age	Service's distribution
	Sex	" "
	Surgeon	Room use pattern
	Cancellations	Potential use for pattern

A note is now made on the slates of actual "skin-to skin" time, not just the booker's estimate plus turnaround. If the starting time of each procedure was also noted, actual turnaround and surgery time could be calculated. Also, if the physician's estimate was added, then a study of the accuracy of his and the booker's estimates could be of value. Instead of recording all emergencies together, it might be useful to note those which "broke" the slate (see section 5.3.9). It would be useful for the data-collector to note features, if any, which cause some operations of a particular service to be done in one OR and other operations to be done in another OR also used for that service.

TABLE VIII (cont.)

LOS	Admission date	Overall admissions rate Potential use in day-of-the-week distribution Potential use in time-cycle study
	Discharge date	Length of stay Potential use in study of occupancy control via LOS
	Service	Patients per service Classification of patients
	Age	Service's distribution
	Sex	" "
	Number of operations	Useful only if decoded to identify OR procedures

Although not available on the tape used, CPHA could provide information on the use of special care units and discharge status, as well as diagnoses.

EMERGENCIES	Time of arrival	Arrival rate
	Time that Admitting was informed	Proportion placed in morning of day-shift
	Time that patient was placed	Potential use in study of of delay
	Service	Emergency patients per service
	Physician	Patient volume per physician
	Bed received	Ward / service pattern
	To OR?	Potential use for proportion
	Age	Service's distribution
	Sex	" "

the year were listed according to the number of procedures done on that day. These sets of days were divided into roughly equal sized groups (strata) aligned by the number of procedures. The desired number of days to sample was determined, and from each stratum the same proportion of days was chosen at random.

Table VIII lists the data items and uses.

7.1.3 Length of Stay

The largest block of data was a magnetic tape of PAS case abstract data for 1974 obtained from the Commission on Professional and Hospital Activities (CPHA). For each patient discharged from the hospital, the Medical Records Library prepares a case abstract of demographic, diagnostic and treatment information, and submits it to the CPHA. This commission assembles the data on magnetic tape files, and analyzes it. The tape which we obtained contained some 21,000 patient records of data items which we had requested, with the rest of the original abstract's information deleted. Table VIII details the information we extracted from those records.

7.1.4 Emergency Admissions

The emergency unit maintains a daily record of admissions as well as a form on each patient admitted. (These forms are liable to disappear if the physician wants them.)

For this study, records covering the period of the waiting-time data were used. A sample drawn from a longer time period could also have been used.

The data usage is described on Table VIII.

7.2 The Specification of Data and Information

Most of the data incorporated in the model have been converted to empirical functions which describe the characteristics for each of the various hospital services. However, some characteristics are identical over all services, and could be represented by simpler single descriptions. Other information, obtained from St. Paul's, determined the structure of the model in such details as the sequence of events or the numbers of beds. A brief description of the data incorporated in the model follows. In cases for which the derivation of data used by the simulation model from the raw collected data is rather involved, a fuller explanation may be found in Appendix 2. The final form of all functions may be found in the program listing, in Appendix 3.

Table IX lists the types of data and information used in the model, and indicates those for which further discussion may be found in the appendix.

Except for a couple of program book-keeping items, event priorities were arranged to cause the following <u>sequence</u> (refer also to Figure 8.1). Each day, the requests for admission were created first. Emergency and DU requests were processed up to, but not including admission. Urgent, semi-urgent and elective

TABLE IX

DATA AND INFORMATION USED

Item Number	Type	More In Appendix ?
1	Event sequencing	
2	Proportion of morning day-shift emergencies	
3	Proportion of long-wait cancellations	
4	Daily patient arrivals (non-schedulable and schedulable) by service	Yes
5	Physicians per service / Physicians' days for surgery	
6	Patient admission diagnostic category	Yes
7	Patient sex	Yes
8	Patient age group	Yes
9	Patient length of stay	Yes
10	Patient pre-operative LOS	
11	Patient length of surgery	Yes
12	Proportion requesting an admission date	
13	Time until requested admission date	
14	Daily bed limit for slate	
15	Daily operating time limit for slate (420 min. * no. of OR's)	
16	Scheduling priority features	
17	Turnaround time	
18	Medical bed limit for morning emergencies	
19	Medical beds allowed for schedulable patients	
20	Alternate areas	
21	Limit on use of off-service beds	
22	Patients to stay in off-service areas	
23	Proportion of patients requesting emergency surgery	
24	Proportion of patients with in-hospital operation requests	

requests were processed in that order as far as being scheduled and queued up. Discharges (which freed beds for the day) were processed next. The first claim on these beds were transfers. A number of emergency patients equal to the proportion which would appear during the morning of the day-shift made the next claim on beds. If there was still room, scheduled patients were admitted next. (Emergency and other in-hospital operation requests were generated from the patients admitted.) The remaining emergency patients (all those not "in the morning") were then placed wherever it was possible. Finally, the calculations regarding the day's operations were done. This arrangement is believed to closely represent the bed-claim sequence at St. Paul's. In particular, the proportion of immediate patients to be handled in the morning of the day-shift was obtained by comparing the number of emergency patients being placed between 6 am and 11 am plus an arbitrary 50% of DU patients with the total number of immediate patients.

The proportion of <u>patients cancelling</u> each week, of those who waited over seven weeks, is fairly arbitrary, based on observed waiting times.

The "Patient Generation Segment" of the model uses a large amount of data. Each of several patient identification items is based on a different function (series of proportions) for each service.

For the arrival distributions, the observed pattern of daily arrivals for each of emergency (with DU) and schedulable categories was smoothed and tailored to acceptable rates for yearly totals. These distributions were used to give the daily arrival rate for each type of patient (see Appendix 2.3).

The number of physicians per service was taken on the basis of an arbitrary "average active" physician. The number of patients for each physician and their characteristics were sampled from the same distributions, so that, in effect, a "composite" physician was used. In Orthopedics, for example, there were nine active staff listed. Most were quite busy during the time observed - so the model evened the patient load and kept nine physicians. At the other extremity, in Medicine, some 33 physicians each admitted from 1 to 35 patients during the time observed. It was decided that at a level of 22 physicians, each could be considered to have a reasonable load. The value of including these composite physicians is partially in identifying physician's blocks on the slate, and partially in defining an "average patient load" to give an idea of the effect of increased or decreased staff.

The proportion of patients in each patient diagnostic category was based on the observed number of emergency cases, known totals of emergency and DU patients, known slated numbers of schedulable patients, and known overall totals. For details, see Appendix 2.2.

The PAS data, together with observed data from slated and emergency cases was used to give the proportion of patients by sex, and, for each sex, the proportion in each age group (see Appendix 2.4).

Length of stay was obtained by a more complex calculation.

From the PAS data, LOS was subdivided by sex, age group, and 3 seasonally-relevant groups of months. It was observed that LOS was dependent on age, but not significantly on time-of-year. The average for each sex was significantly different, but a simple calculation (included in Appendix 2.5) showed that this was almost entirely accounted for by age-sex patterns (i.e. there were many more elderly females - which boosted the female average stay). Hence age groups were assigned by sex, then LOS by age group. Furthermore, theoretical considerations and the existing literature suggested that the best parametric distribution to represent LOS would be the log-normal. A rough test of this hypothesis was done by plotting points on logarithmic probability paper. Although not giving an acceptably straight line (to support the log-normal hypothesis), these plots were helpful. Actually, for some service-age groups, the graph and even a chi-square test supported the log-normal hypothesis. For most groups, however, the data deviated sufficiently from log-normality that the parametric distribution was avoided. Empirical distributions were used for LOS, including a number of intermediate points obtained from the graphs of the computer-tabulation of PAS data. (Appendix 2.5 contains a more complete description.)

Pre-operative stay was assigned according to distributions based on the physicians' admission forms.

The data collected on length of surgery was also tabulated by age group and sex. Although in EENT, the average length varied greatly by sex in the first three of the age groups, the hospital could offer no explanation. Variation was relatively small for Orthopedics. Hence, in the surgical services modelled, age was taken to be the only dependent variable in assigning length of surgery. Empirical data was smoothed arbitrarily and used as input (see Appendix 2.6).

The proportion of patients requesting a date for surgery (by diagnostic category) was based entirely on empirical data. When a date was requested, in reality it was almost always on the day of the week for which the physician was booked. For each request then, there was a certain delay between the next date for which the appropriate physician was booked, and the date which was requested. The empirical data was processed and smoothed to determine which proportion of patients would request a date any given number of weeks from the next booked date. Unfortunately, the date selected in the model is entirely random, whereas the physician would hopefully have some idea of his next free day, or of whether he wanted to "bump" one of his own patients (see also Figure 8.2).

The bed limit per day and the time limit (based on the number of OR's used) were as indicated by the hospital.

Scheduling priority was represented by the following decision mechanism: (i) patients for whom no specific date was requested could be scheduled no less than eight days away (corresponding to the requirement that the physician submit his forms at least eight days in advance), (ii) true urgent cases (no requested date or requested within two weeks) could bump lower-category patients of the the same physician, (iii) bumped patients were replaced one week later (if possible), (iv) cancelled patients were re-scheduled on an urgent basis, (v) patients could only use OR's of their own service, (vi) non-urgent cases had to be handled on a correct block day. Figures 8.3 and 8.4 include these considerations.

Since only the total daily time per OR was of interest, instead of making the time between operations dependent on the lengths of adjacent operations, a constant turnaround time of fifteen minutes seemed reasonable (see also Section 5.3.7).

The placement of Medical patients presented a problem. In reality, teaching residents control some of the Medical beds, and there are many emergency Medical admissions beyond the capacity of the Medical wards. Since data are not available on the proportion of each category of patient using teaching beds, or on the difference in LOS, or on the actual use made of teaching beds, they cannot be distinguished in the model. In an effort to keep in mind the effect of the teaching beds, and to "tune" the model, morning emergencies were allowed up to a certain number of Medical beds. When it was time to admit scheduled patients for the day, the length of the queue and the number of available beds were noted. Depending on the number of available beds, the number of patients to admit was determined. Furthermore, if the waiting line was long, extra patients were admitted. If it was short, less patients were admitted. This was implemented by specifying an upper and lower limit on acceptable queue length, then defining three functions (one for long, one for acceptable, and one for short queues) specifying the number of patients to admit at each level of "remaining capacity". The limits and numbers are arbitrary.

When emergency patients cannot be admitted to the proper area, they are placed in an alternate area. There is an arbitrary limit defining the number of beds which may not be used by off-service patients. Data suggest which sequence of alternate areas sould be checked for empty beds. Service area "2" is used in this model as an overflow area. (Overflow beds are necessary because Medical emergency patients actually use extra beds in many service areas, not just those implemented in the model.) For Medical patients in surgical beds, transfers are arranged to avoid excessive "No Bed" situations. Off-service data and consultation with the hospital suggest the proportion of other types of patients allowed to stay in off-service beds.

The number of beds per service reflects the actual situation. However, the allotment for Medicine includes the ICU, and the Activation beds are divided approximately by use as 6 for Medicine, 5 for Orthopedics, and 5 for General Surgery.

The total number of emergency requests on the OR was found from data. The OR Booking Office, and some data, suggested the number of in-hospital demands on the OR per day (if these could not be placed within a week, they were handled as emergencies). These were included in the model by having an appropriate proportion of the admitted patients request such special surgery.

7.3 Comments

The adequacy of the data used in the model should be discussed. Were the data too old? Were the observed samples too small, or faulty? Were any important features included or omitted without adequate data substantiation? Would other types of data have been helpful?

Let us consider the four data collection groups identified. The waiting lists were disappointing in that the sample was small, so Section 11.1 includes some suggestions regarding sample collection. The Medical admitting forms moved especially slowly during the collection time - at about one third of the normal rate! Furthermore, the fact that teaching residents decide whom to admit to their area and when, yields data which deny any analytical pattern based on such criteria as patient admission diagnostic category, and FIFO. Data on operations were taken from a good sample. However, the OR supervisory staff suggests that difficulty of operations (and hence their length) has increased somewhat since 1974, so that newer data might show slight changes. The LOS data were also taken from a large sample. The removal of the pediatric specialty from the hospital has probably had a slightly different effect than that calculated, but these data should be quite accurate. Emergency admissions gave good data (except that a sample selected from the entire year might be preferable).

As mentioned before, it might be preferable to modify the model so that the length of time to a requested admission date is not random. This would require a closer observation of individual physician's practice.

It would also be preferable to have a less rigid daily bed limit for scheduled surgical patients. This would require observance of the final slate as it emerges - with a knowledge of which patients are scheduled and which patients are in-hospital.

The main unavailable information which would be of value is a study of transfers between service areas - with a knowledge of which were corrections of off-service placement. The total number of patients placed off-service for each service (not just Medicine) would also help.

CHAPTER 8 THE MODEL IMPLEMENTATION

This chapter explains the actual concepts involved in the programmed model, and briefly summarizes its contents. The entire computer program is listed in Appendix 3.

At present, three services have been implemented in the model: Medicine, EENT, and Orthopedics.

8.1 General Features

There are probably three features of the program which should be explained first. These are: (i) the idea of a "composite" physician, (ii) the implementation of the surgical slates, and (iii) the daily sequence of events which the model observes.

(i) In order to relate patient load to the number of active physicians, it was considered desirable that each service have a certain number of physicians, and that each patient have a particular physician. In this manner, it would be easier to suggest the effect on patient load of increasing or decreasing the number of physicians on staff. However, physician practice patterns are by no means similar. Some physicians admit many patients, some very few. Some physicians consider all their patients to be semi-urgent, others all elective. Some physicians request specific admission days for all of their patients, others for a few, others for none. Because of this variety, and because in increasing or decreasing the active staff only a "typical" physician can be considered easily, it was felt that a "composite" physician should be used (already mentioned in Section 7.2). Hence, except for random variations, all physicians in the model have identical practice patterns. Furthermore, rather than having a specified patient load generated for each physician, the language is better structured to generate patients, and then to assign a physician to each. As a result, if the staff size is to be varied, in addition to changing the number of physicians for the service it will be necessary to re-compute the proportion of schedulable and DU patients attributable to the physicians in question, and to re-construct the patient arrival rate and admission diagnostic category functions. It may also be necessary to adjust certain limits on patient flow. Refer to Chapter 10 for examples.

(ii) The main scheduling device in the OR Booking Office at the hospital is a six-week visual slate file. The counterparts of this file in the program are matrices counting the scheduled number and total time of patients to be operated on each week, and corresponding chains on which complete patient data for each operation are filed. For each surgical service there is a matrix, the first row of which gives the "dates" of Monday through Friday of the present week. Each of the six pairs of rows after that corresponds to a particular week in the future. The first row of each pair stores the number of patients to be admitted and operated on for each day of the week. The second row of each pair accumulates the operating time (and turnaround time) required by these patients as well as in-patients. These are the two critical factors determining whether another patient may have surgery on a given day (refer also to Section 9.1).

The time calculations work as follows. Each operating theatre is slated from 8:00 am to 3:30 pm with a half hour for lunch, which gives 420 minutes to be used. Turnaround time of fifteen minutes is added between patients. However, it is assumed that one turnaround could proceed during the lunch break. Since only total operating time per service per day is of interest, the "over-lunch" turnaround is counted as falling between the first pair of patients - and no time is added for that.

For each of the six weeks mentioned above, in addition to the matrix there is also a "chain" for each service. Data-entities representing the patients to be operated on are filed on the chain. To avoid shifting data between rows and between chains, there is a pointer which indicates which rows and chain are those of the "present" week. This pointer changes weekly, cycling through the sets.

(iii) The <u>daily sequence of events</u> (effected by priority levels) was mentioned in Chapter 7, but is worthy of repetition here. Figure 8.1 depicts the time stream. The first and last things done each day are "book-keeping" events. Of the patient-related events, the generation of patient admission requests for all categories of patients is done first. Priorities are set in such a way that, of the schedulable patients, urgent requests are processed first, then semi-urgent

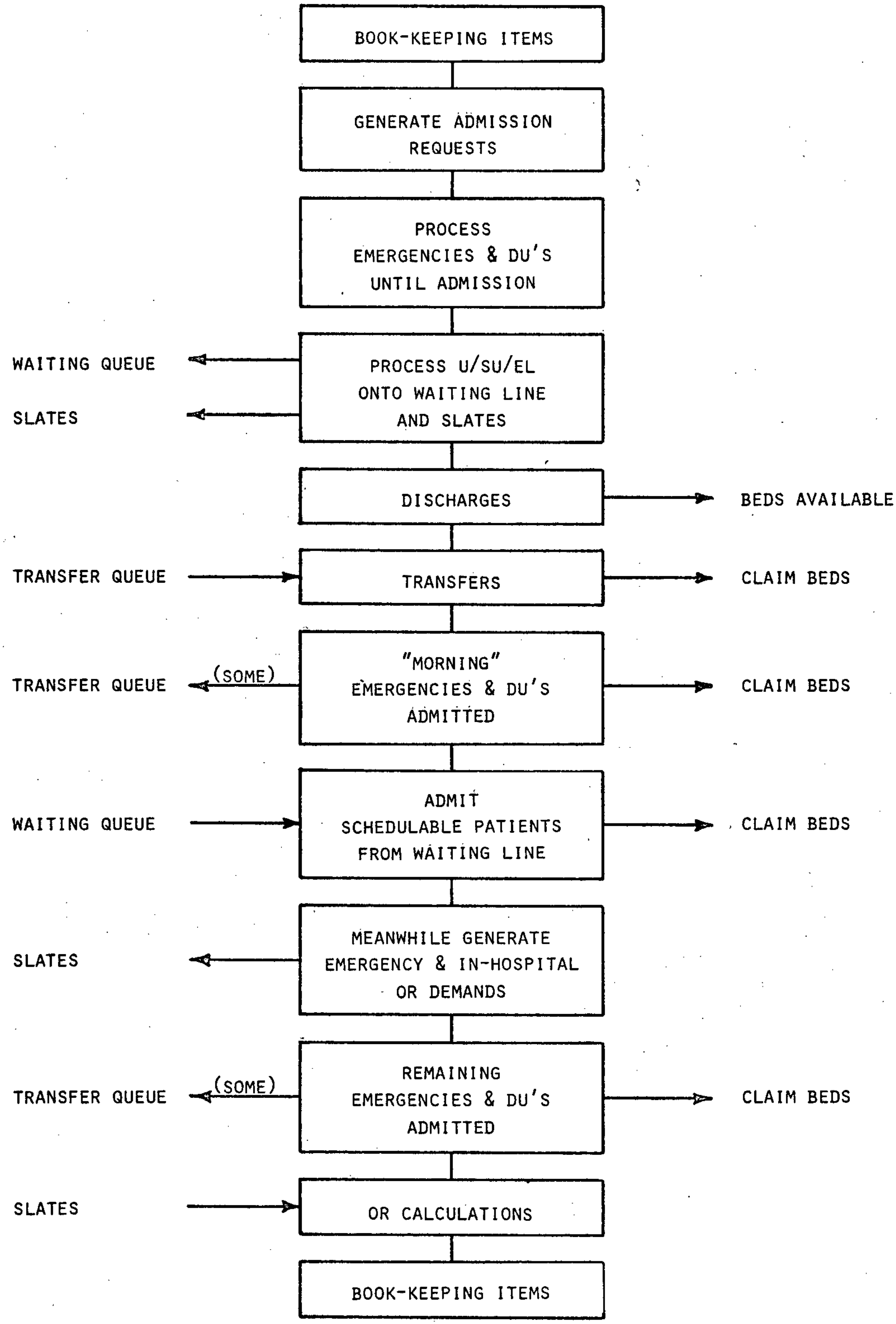

Fig. 8.1 Flowchart for daily time stream

ones, then the electives. Also, each request is completely processed before beginning the next. Then, of the events which affect bed occupancy, discharges are first. Transfers within the hospital follow. An appropriate proportion of emergencies to be placed during the morning of the day-shift come next. Scheduled admissions then make their claim on beds, followed by the rest of the emergencies for the day. To close off, the day's OR data is computed. This sequence is intended to result in a realistic simulation of waiting time, "No Bed" cancellations for scheduled patients, and off-service placement of emergency patients.

8.2 The Program Segments

The program listing begins with an extensive table of definitions for reference, followed by different categories of GPSS definitions. The remainder of the listing is divided into sections by comment lines. These sections are briefly explained below.

8.2.1 Housekeeping Segments

The first segment in the program updates the slate file each "Saturday" (the sixth day of each seven). The pointer mentioned in Section 8.1 is moved to a new "present week". Data on the week just completed is erased. Patients whose forms had not been placed on the six-week "visual file" (due to a specific request or lack of space) had been filed in a separate place. As many of these as is appropriate are now moved onto the new "fifth week" location. Weekly date changes are made.

The last two program segments are also for "housekeeping". The first of these is to control print-outs as desired. The final program segment is a timer. It keeps track of how many days the program has run, and helps with some data gathering.

8.2.2 Patient Generation

A transaction is released daily and marked with the date. (Each entity which moves through the model is called a transaction. As in this case, use of the term in this thesis is normally to identify an internal program entity, as opposed to a transaction which represents a patient - which will usually be called a patient.) Then for each service, the transaction "splits" to generate first the non-schedulable then the schedulable patient admission requests in accordance with the appropriate arrival distributions for that service. This generating transaction leaves the model, and the requests are sent to be assigned patient characteristics.

To each patient, the model assigns a physician, an admission diagnostic category, a sex, an age group, and a LOS. Emergency requests are then diverted, as are the remaining Medical and surgical requests.

8.2.3 Surgical Request Handling

For surgical requests, pre-operative LOS (making sure total LOS is longer) and length of surgery must be assigned. Then the patient requests are separated according to the booking method observed by their service (e.g. block booking, see Section 5.3.4). (Only block booking is implemented in the model at the time of writing.)

As shown in Figure 8.2, the first item to be determined is a date on which to attempt to schedule surgery. This date may either be "as soon as possible" or may be requested for some time in the future. It is necessary to decide which patients are to have a requested date of surgery. For these, that date is determined in accordance with empirical data (Section 7.2). For the others, the earliest possible date of surgery which is blocked for the proper surgeon is determined. It must be over seven days away since the physician is required to submit his requests at least eight days in advance. Having a desired date for surgery, one may attempt to schedule the patient, as in Figure 8.3.

If the date is over six weeks away, the request is placed on a chain corresponding to the file box - separate from the main six-week file. Another copy of the request is added to an admission chain to wait for the appropriate day.

If the date is within six weeks, the operations already scheduled for that date are checked. Were this one added, would the bed or time limits be exceeded? If there is room, the

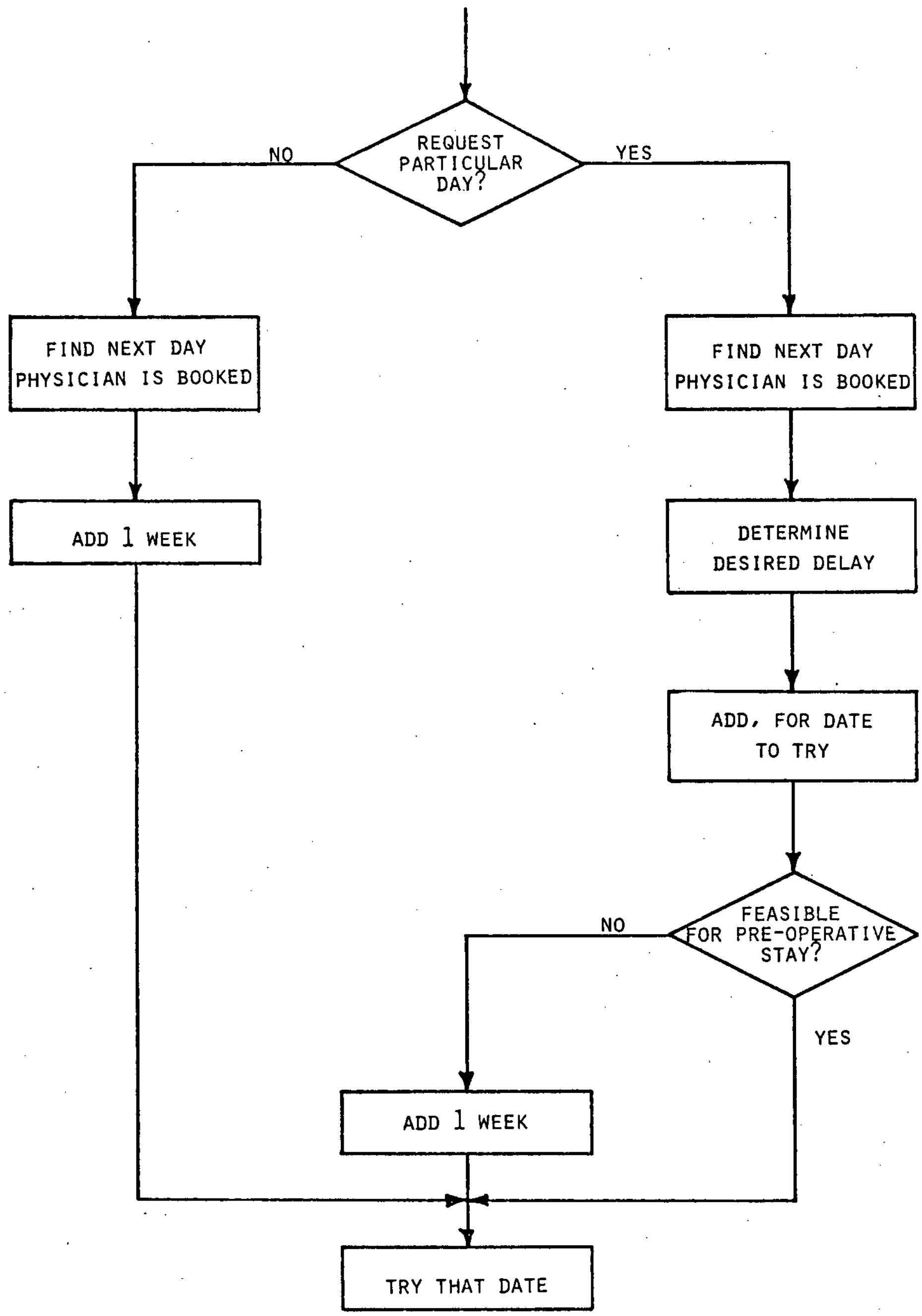

Fig. 8.2 Flowchart for first desired surgery date

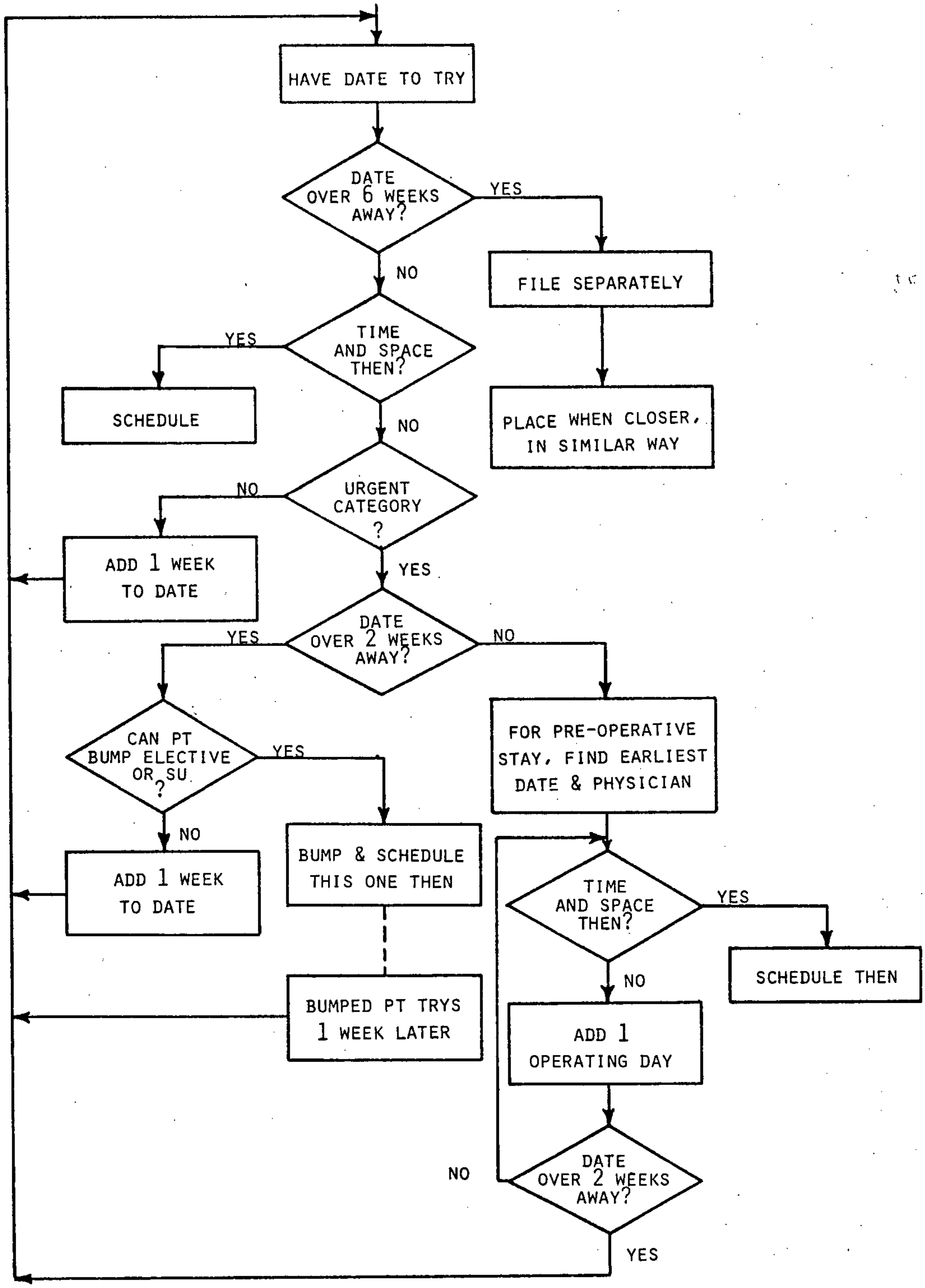

Fig. 8.3 Flowchart for placing schedulable surgical patients on the slate

patient is added there. If there is no room, a later date must be found as follows.

For a non-urgent request, there will be an attempt to schedule it one week later.

It is considered that an urgent request for a date beyond two weeks away is one which is not really top-priority, but is more important than non-urgent requests of the same physician. Hence, the model will try to bump an elective first, or a semi-urgent, from the desired day. If there is none which would allow the new patient room and time, a week is added before trying again. Note that urgent patients are supposed to be admitted within two weeks. As a result, if a request is being handled in this part of the model it is because the physician submitted it with a long-term "urgent" requested date. The model only allows him to bump his own patients.

An urgent request which did not come asking specifically for admission two or more weeks away is considered to desire admission as soon as possible. If it cannot be fit into the proper physician's slot, the earliest possible date is found, regardless of physician. The patient is added to the first day with enough space and time. If there are none within two weeks, this request bumps another, as above.

Patients who were bumped must be removed from the slates and taken out of the admission file. A week is added to the date originally obtained before trying again.

Once a day is obtained for any of these requests, the successful surgery date, and hence, admission date is marked.

The request is added to the slate and to the admission file.

8.2.4 Medical Request Handling

A Medical request is simply added to the queue of those awaiting admission.

8.2.5 Surgical Admissions

Once a day, the surgical admissions for that date are released from the waiting queue. Admission proceeds as shown in Figure 8.4. Some who should be admitted find no room available. These are "No Bed" patients. Their category level is reset so that they will be treated as high-priority urgent requests. They are removed from the slate to be tried one week later. The category is restored once a new date is found.

For the patients who are admitted, there is another process. A certain proportion of the patients in the hospital will have extra operations - besides that for which they were originally admitted. In order to represent these demands on the OR, it was decided to use the patients being admitted to initiate demands for emergency and in-hospital operations. Emergencies are generated and set for the next day (if the patient's LOS warrants using him). In-hospital requests are more complex, as they must be scheduled. For them, checking begins two days from the present time, or if that day would be on a weekend, checking begins with the following Monday).

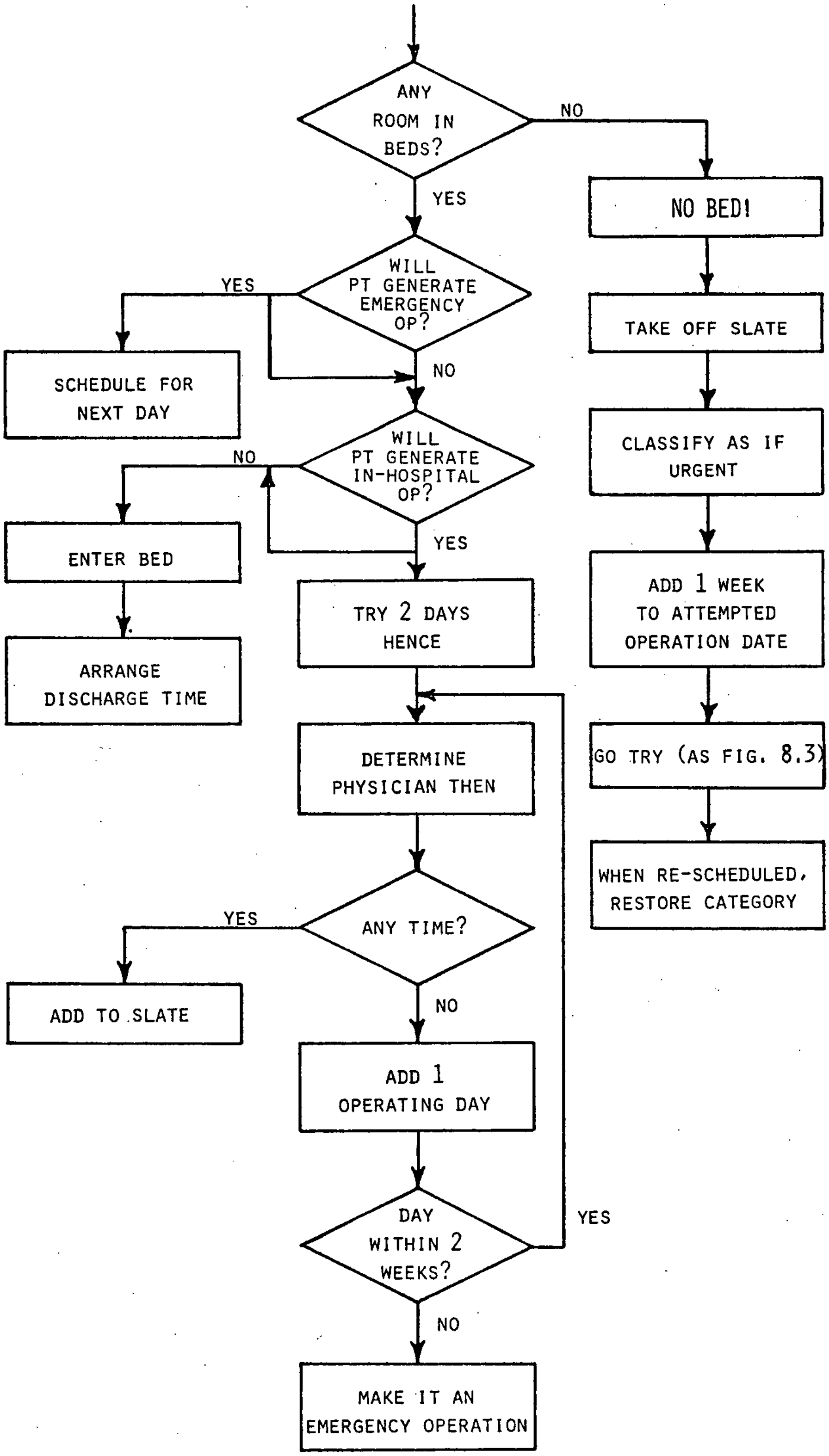

Fig. 8.4 Flowchart for admitting surgical patients

Having decided the date, the physician who operates then must be identified. One may now check whether the date is possible, or go on looking until one is. (Recall that "possible" requires only enough time. The patient already has a bed). Once a date is found, the model checks to be sure that the patient will still be in the hospital (or else ignores this request). If the patient will be in the hospital, the operation is scheduled on the slate. Note that if an in-hospital request cannot be scheduled within two weeks, it is changed to emergency handling.

Now, the remaining details for an entering patient are taken care of. He is put in a bed and appropriate statistics are gathered. According to his LOS, he is scheduled for discharge.

8.2.6 Medical Admissions

Each day, when the time comes to admit Medical patients from the waiting line, the number of beds available and the length of the queue are determined. Depending on the amount of space, a decision is made concerning how many beds to allow these patients to take. Furthermore, if the waiting line is long, extra patients are allowed in; if it is short, less are admitted. (The algorithm is discussed in Section 7.2.)

The admitted patients are put in beds and appropriate statistics are gathered. According to their LOS, they are filed for discharge.

8.2.7 Emergency Admissions

Figure 8.5 depicts emergency admissions.

Note that both emergency and DU patients are handled identically. Since the entire day is treated as one time unit, proper DU processing is not possible. Morning day-shift and other arrivals are differentiated (by proportions) to affect sequencing. The morning ones are allowed to claim beds after discharges and transfers, but before scheduled admissions. The rest wait until after regular admissions.

As with the other patients admitted, a proportion of these arrivals cause emergency and in-hospital operation requests. These emergencies, however, are considered to happen on the same day.

If a bed is available in the proper area (and the patient would not exceed an allowable limit) the patient is put in the bed and on the discharge file. Otherwise, admission is permitted to an alternate area (except for restrictions there also). Any Medical patients who must be placed in surgical beds are also put on a special file. (See Section 8.2.8 regarding their transfers.) Other patients placed in surgical beds are allowed to stay if a specified number of beds are still free in that area. A proportion of the patients placed in the overflow area are allowed to stay there. The rest are filed to cause transfers the next day.

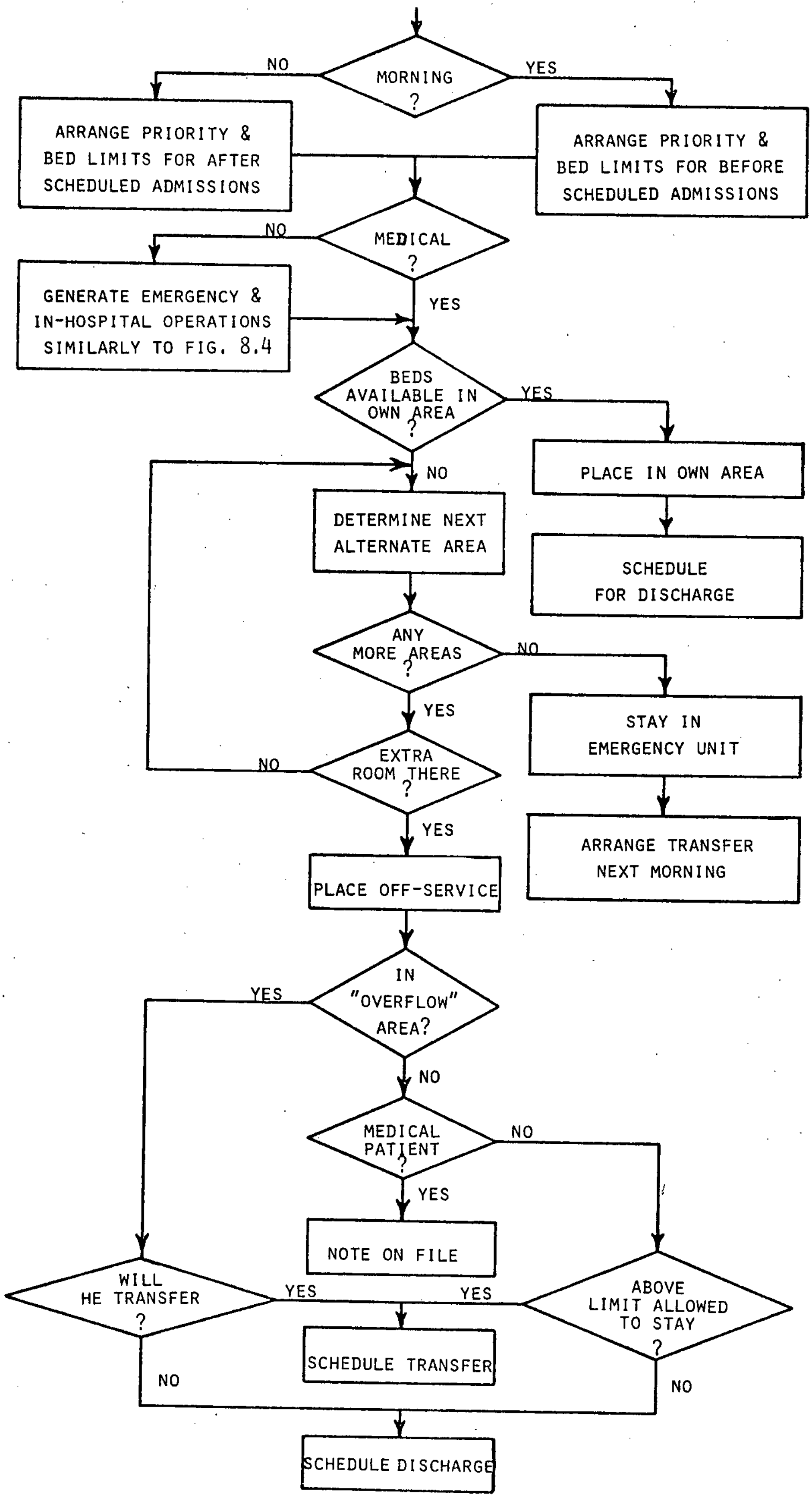

Fig. 8.5 Flowchart for emergency admissions

8.2.8 In-Hospital Transfers

These happen right after discharges, assuring that transferring patients get first claim on released beds "each morning". The surgical areas are checked to see whether there are enough beds free to allow admission of slated surgical patients. If not, enough Medical patients are transferred out of the areas to avoid excessive "No Bed" cancellations. For patients to be transferred, if there are beds in the proper area, they are taken from the off-service area and placed in the proper service area.

8.2.9 Discharges

This is the first change affecting census each day. All the patients scheduled to leave today are discharged, and appropriate records are kept.

8.2.10 Operating Room Data

Note that, as far as operations go, the length of time scheduled is the actual length of time operated. (Any problem due to violation of this assumption warrants and can be covered by an independent, specific study.) Turnaround time is included as explained in Section 7.2.

All of the day's emergency and regularly scheduled patients to be operated on are released for processing. For emergency operations and for each service's scheduled operations, the total times and patients are accumulated and tabulated each day.

CHAPTER 9 EVALUATION OF THE SIMULATION MODEL

This chapter discusses the "behaviour" of the St. Paul's simulation model. The form of the results given by the simulation program is explained. This is followed by an explanation of the verification and validation of the model:

Verification is a check that the model behaves internally as the modeller intends.

Validation is the process which tests that the model provides a reasonable representation of reality.

(Fishman and Kiviat, 1967)

9.1 Form of the Results

A simulation run in GPSS automatically generates a "standard" set of statistical results describing the behaviour of the model. If the programmer uses any matrices in the program, or specifies the format of any frequency tables (of waiting times, for instance), they will be included in the print-out. The language also allows the monitoring of each "transaction" (normally a patient) on any specified file or at any specified location in the model. As the output from such monitoring may be voluminous, it tends to be useful only for debugging or verification purposes. In addition, it is possible to arrange for GPSS to print out any subset of the total available information. The following discussion includes all results which are provided by GPSS without needing to be specified.

First it should be noted that several of the items are cumulative averages over time (cumulative sums divided by the total time). If a run is long, the effect of the most recent time interval is weighted less and less due to the effect of preceding ones. To avoid this, a "RESET" between "START" blocks allows information on individual time intervals to be generated and displayed.

All averages printed with the "tables" such as those of waiting times or LOS represent patients who have completed the particular process being monitored. The averages listed elsewhere may be slightly biased due to the fact that they count all patient-days spent in the process since the start of the current time interval, and divide by the elapsed time since then. Inaccuracies result if patients are being processed at the start of the time interval and if any are being processed at the time of print-out. Schribner's text Simulation Using GPSS (1974) and the GPSS manual point out these biases more completely.

The first items printed in the standard output are "block counts". Each functional statement (as opposed to "comment" statement) in GPSS is a "block". For each "block" - which is numbered on assembly - there is a count of the current and total number of times it was used. Since these counts are useful only for carefully following the flow through the model, no examples are included in this description.

Any time a "transaction" (patient) must be filed for a period of time before being used again, it is most efficient to place the transaction on a "user chain". In the print-out, "user chain" information (see Table X), follows the "block" counts. SLEW1-6 are for the six one-week chains of EENT patients slated for operations. The "current contents" columns for the various weeks identify how many patients are waiting for operations and when they are scheduled. (The number for the present week, probably the largest, may not be the first, due to cycling as explained in Section 8.1.) SLEEN gives similar information on EENT patients to be scheduled beyond six weeks away. SLOW1-6 and SLOEN give the same information for Orthopedic patients. ADMSC identifies the current, maximum, average and total number waiting for admission for surgery, as well as the average time waited. This information is useful for validation. A similar and very critical set of values concerns ADMMC, which is the chain of Medical patients awaiting admission. EMRGC provides information (probably of little use) on those in line for emergency surgery. MALTn identifies the number of Medical patients in surgical bed areas, where n=3 for EENT and n=4 for Orthopedics. The average numbers may be useful for experiments. XFERC identifies other patients off-service and in line to be transferred back. DISCH (together with XFERC and MALT3-4) identifies the total number of patients in the hospital, all of whom are on file to be discharged.

The information on "storages" (bed pools, Table XI) is quite useful. It gives details on the utilization of each bed area (1=Medicine, 2=overflow, 3=EENT, 4=Orthopedics). The

TABLE X

USER CHAINS

USER CHAIN	TOTAL ENTRIES	AVERAGE TIME/TRANS	CURRENT CONTENTS	AVERAGE CONTENTS	MAXIMUM CONTENTS
SLEW1	40	4.875	9	6.964	29
SLEW2	35	10.085	6	12.607	29
SLEW3	30	12.000	2	12.857	28
SLEW4	29	15.137	2	15.678	27
SLEW5	23	12.739	23	10.464	23
SLEW6	11	6.454	11	2.535	11
SLEEN	6	11.833		2.535	5
SLOW1	36	5.472	14	7.035	21
SLOW2	24	10.500	5	9.000	18
SLOW3	20	13.349		9.535	18
SLOW4	21	11.047	1	8.285	18
SLOW5	16	15.937	16	9.107	16
SLOW6	15	7.599	15	4.071	15
SLOEN	5	5.599		.999	3
ADMSC	284	10.193	104	103.392	137
ADMMC	124	5.354	24	23.714	34
DISCH	909	8.102	249	263.035	279
EMRGC	34	.500		.607	6
XFERC	16	1.000		.571	4
MALT3	61	3.803	17	8.285	17
MALT4	38	8.578	5	11.642	21

TABLE XI

```
****************************************
*                                      *
*              STORAGES                *
*                                      *
****************************************
```

STORAGE	CAPACITY	AVERAGE CONTENTS	ENTRIES	AVERAGE TIME/UNIT	-AVERAGE UTILIZATION DURING- TOTAL TIME	AVAIL. TIME	UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	CURRENT CONTENTS	MAXIMUM CONTENTS
1	165	164.321	526	8.747	.995				100.0	165	165
2	100	9.000	35	7.200	.090				100.0	10	16
3	35	32.250	210	4.300	.921				100.0	35	35
4	75	71.750	212	9.476	.956				100.0	67	75

TABLE XII

```
****************************************
*                                      *
*               QUEUES                 *
*                                      *
****************************************
```

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
WMEDU	18	11.071	65		.0	4.769	4.769	7	12
WMEDS	8	4.107	22		.0	5.227	5.227	8	3
WMEDE	15	9.178	50		.0	5.139	5.139	9	14
WEENU	3	1.321	4		.0	9.250	9.250	10	1
WEENS	2	.678	3		.0	6.333	6.333	11	1
WEENE	88	66.357	183	1	.5	10.153	10.208	12	83
WORPU	1	.392	1		.0	11.000	11.000	13	
WORPS	12	8.964	23		.0	10.913	10.913	14	7
WORPE	50	40.428	109		.0	10.385	10.385	15	50
LOSME	199	187.250	620		.0	8.456	8.456	16	186
LOSMM	114	101.857	326		.0	8.748	8.748		105
LOSMF	99	85.392	294		.0	8.132	8.132		81
LOSEE	33	22.857	145		.0	4.413	4.413	17	24
LOSEM	24	11.321	72		.0	4.402	4.402		16
LOSEF	18	11.535	73		.0	4.424	4.424		8
LOSOR	78	67.214	192		.0	9.802	9.802	18	67
LOSOM	38	32.571	97		.0	9.402	9.402		33
LOSOF	43	34.642	95		.0	10.210	10.210		34
MIN2	12	7.500	22		.0	9.545	9.545		5
MIN3	18	9.964	68		.0	4.102	4.102		11
MIN4	14	5.464	27		.0	5.666	5.666		5
EIN2	3	.392	4		.0	2.750	2.750		
EIN4	2	.285	3		.0	2.666	2.666		
OIN2	7	1.107	9		.0	3.444	3.444		5
OIN3	1	.107	3		.0	1.000	1.000		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES "average utilization during total time" is the most useful variable. "Average contents" may be interesting when compared with off-service usage. "Current contents" is useful for day-to-day examination.

The queue information (Table XII) is similar to that for "user chains". Those queues having an entry under "Table Number" are more completely described in a table. At a glance, the queue output gives information on waits for urgent, semi-urgent and elective patients of Medical, EENT and Orthopedic patients (WMEDU, WMEDS, WMEDE, WEENU, ... ,WORPU, ...). Overall LOS for each service may be found (LOSME, LOSEE, LOSOR), as well as LOS by sex within each service (LOSMM, LOSMF, ...). The picture by sex, in giving the average numbers in the hospital, suggests bed disposition. Also, a quantification of LOS difference by sex appears. Finally, for each service there are queues of those off-service. (eg. MIN3 means Medicals in area 3 - EENT beds). Of these the averages in each area and overall average off-service may be informative.

The format of all the "tables" is identical (see Table XIII for examples). Their mean and standard deviation figures are unbiased. The frequency distribution tables may be of use. To identify what each "table" shows, see the list in Table XIV. Information may be for verification, validation, or experimentation.

TABLE XIII

OUTPUT TABLES

TABLE ORPSN

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS
20	3.799	1.238	76.000

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-3.068
1	1	4.99	4.9	95.0	.263	-2.261
2	3	14.99	19.9	80.0	.526	-1.453
3	1	4.99	24.9	75.0	.789	-.646
4	10	50.00	74.9	25.0	1.052	.161
5	4	19.99	94.9	5.0	1.315	.969
6	1	4.99	100.0	.0	1.578	1.776

REMAINING FREQUENCIES ARE ALL ZERO

TABLE ORPST

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS
20	289.500	115.000	5790.000

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.517
60	0	.00	.0	100.0	.207	-1.995
120	3	14.99	14.9	85.0	.414	-1.473
180	2	9.99	24.9	75.0	.621	-.952
240	1	4.99	29.9	70.0	.829	-.430
300	2	9.99	39.9	60.0	1.036	.091
360	6	29.99	69.9	30.0	1.243	.613
420	6	29.99	100.0	.0	1.450	1.134

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WTU1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS
50	6.039	1.046	302.000

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-5.769
2	0	.00	.0	100.0	.331	-3.859
4	4	7.99	7.9	92.0	.662	-1.948
6	28	55.99	63.9	36.0	.993	-.038
8	18	35.99	100.0	.0	1.324	1.872

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WTS1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS
11	5.909	1.511	65.000

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-3.908
2	0	.00	.0	100.0	.338	-2.585
4	3	27.27	27.2	72.7	.676	-1.262
6	2	18.18	45.4	54.5	1.015	.060
8	6	54.54	100.0	.0	1.353	1.383

REMAINING FREQUENCIES ARE ALL ZERO

TABLE WTE1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS
46	6.739	1.371	310.000

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-4.915
2	0	.00	.0	100.0	.296	-3.456
4	3	6.52	6.5	93.4	.593	-1.997
6	18	39.13	45.6	54.3	.890	-.539
8	21	45.65	91.3	8.6	1.187	.919
10	4	8.69	100.0	.0	1.483	2.378

REMAINING FREQUENCIES ARE ALL ZERO

TABLE XIV

MODEL OUTPUT TABLES LIST

Name	Purpose
EENSN	Number of EENT patients slated each weekday
EENST	Total time for EENT patients slated each weekday
ORPSN	Number of Orthopedic patients slated each weekday
ORPST	Total time for Orthopedic patients slated each weekday
WTU1	Medical urgent patients' waiting time
WTS1	Medical semi-urgent patients' waiting time
WTE1	Medical elective patients' waiting time
WTU3	EENT urgent patients' waiting time
WTS3	EENT semi-urgent patients' waiting time
WTE3	EENT elective patients' waiting time
WTU4	Orthopedic urgent patients' waiting time
WTS4	Orthopedic semi-urgent patients' waiting time
WTE4	Orthopedic elective patients' waiting time
STA1	LOS for Medical patients
STA3	LOS for EENT patients
STA4	LOS for Orthopedic patients
EMTBN	Number of (combined) patients daily for emergency surgery
EMTBT	Total time for (combined) patients daily for emergency surgery
EMGDU	Total daily number of emergency and DU arrivals
NOBED	Total daily cancellations for "No Bed"

Following the tables, the "halfword savevalues" are printed. Most of these are internal and not too helpful. However, the following three may be useful:

CANCL = Number who cancelled from surgery due to a very long wait.

MADIS = Number of discharges from the Medical area, since this is not identical to Medical patients' discharges.

MEMRN = Number of Medical emergencies and DU's in the morning. This has an impact on the day-to-day queue.

Several very important "halfword matrices", as in Table XV, follow these. There is a matrix of patient numbers for each service implemented. Rows 1-5 correspond to the Emergent / DU / U / SU / El diagnostic categories. Row 6 is the total of those. The columns are as follows:

1. Patients generated,
2. Patients admitted,
3. Patients requesting a particular date,
4. Patients getting that date,
5. Patients placed off-service,
6. Patients returned to the proper service area.

Note that the number of patients getting a requested date should be lower in the model than in reality, since in the model the date is entirely random and in reality the physician requesting a date should know when he has free time.

Two more types of matrices are printed, but have not been

TABLE XV

HALFWORD MATRICES

HALFWORD MATRIX MEDNO

ROW/COLUMN	1	2	3	4	5	6
1	1863	1863	0	0	557	146
2	472	472	0	0	145	39
3	333	328	0	0	0	0
4	117	116	0	0	0	0
5	321	316	0	0	0	0
6	3106	3095	0	0	702	185

HALFWORD MATRIX EENNO

ROW/COLUMN	1	2	3	4	5	6
1	92	92	0	0	29	9
2	24	24	0	0	6	1
3	21	21	10	7	0	0
4	26	28	27	20	0	0
5	701	689	478	449	0	0
6	864	854	515	476	35	10

HALFWORD MATRIX ORPNO

ROW/COLUMN	1	2	3	4	5	6
1	333	333	0	0	46	20
2	115	115	0	0	12	6
3	9	9	8	6	0	0
4	87	91	80	65	0	0
5	389	389	96	76	0	0
6	933	937	184	147	58	26

shown in the figures as their use is primarily internal. The first of these are the slate matrices for the surgical services. They are explained in Section 8.1. The last item is a matrix of allowable alternate areas. The rows correspond to the service of the patient. The columns correspond to allowable alternative areas. That of column 3 is tried first, then column 2, then column 1. In this implementation area "2" is for overflow. "0" means "stay in the emergency unit overnight".

9.2 Verification

Several tests were performed to ensure that the model behaved in a consistent manner and worked as intended.

One concern in any simulation based on "random" elements is the accuracy of the pseudo-random number generators used. GPSS provides an algorithm for eight identical built-in generators. For certain procedures, such as those in which a proportion of patients are routed one way in the model and the rest another, the system uses generator 1. For others, the choice of a generator is at the programmer's discretion. The generators have been aligned in such a way that the sequence of patients generated, and their characteristics, can be duplicated in consecutive experimental runs. The length-of-surgery functions, however, have been assigned to generator 1. (This was done since generator 1 necessarily determines the proportion, and hence number and sequence, of patients demanding emergency and in-hospital operations - which require lengths-of-surgery.)

Also, generator 1 controls the pattern of requested dates for operations. As a result, almost any change in the model will alter the construction of the slates.

Several tests were performed to check that the numbers generated "fit" a uniformly flat distribution on the 0-1 interval. The proportion of "morning day-shift" emergencies was checked, as well as the proportion of patients transferring and the proportions of patients in the different diagnostic categories. The proportion of surgical patients requesting a particular date was also tested. Each was acceptably close to the intended value - tending to get closer the larger the sample. (e.g. for 22,000 "immediate" Medical patients, the proportion in each diagnostic category was accurate to within 0.2%.)

The random number seeds were changed and long runs were done, to test the repeatability of the processes despite different pseudo-random number streams. Figures 9.1 to 9.6 show the results for one four-year run (after one year of initialization) with print-outs each three months. Figures 9.7 to 9.12 show a one-year run with print-outs each four weeks. (These figures, which are referred to several times in this chapter, may be found at the end of the chapter.) The one-year run is actually a closer look at the third of the four years, during which the number of off-service Medical placements was near the average and there were no extreme fluctuations in output variables. The graphic results show the typical variances in model performance variables. Other runs yielded similar results. A discussion of the individual items appears in Section 9.3, but for the present purpose the results demonstrate that the model is stable.

The different random number generators were also reallocated (so that, instead of being aligned by service, the assignment of generators to functions was shuffled) to test any chance of correlation in the streams dependent on a particular generator. There was no noticeable difference in the range of output variables.

To check both the generator and the function specified, a separate test was done on the Medical arrival functions. The mean rates were within 1% of those desired, and the frequency distribution suitably matched that specified by the function.

For verification purposes the length-of-surgery distribution was replaced by a constant. This demonstrated that time and bed limits were being properly observed during the development of the slate. As intended, the total amount of time slated each day was an integral multiple of the constant value specified per procedure (plus turnaround time).

In another run, the distributions of arrival rates and LOS were replaced by constant values near the original mean values. These values showed up as intended on the LOS tables and "patients generated" columns of the "patient numbers matrices". In addition, the waiting queues and numbers placed off-service stabilized considerably. This was expected, since the two main sources of variation had been removed.

LOS of patients in the model depended first on sex, which was used to determine the age group, which in turn was used to determine the LOS. Despite this complication, the overall distribution matched the empirical data quite well, with one year averages within 5% of originals (as modified to remove Pediatric patients). For both sets of data (empirical and simulated) the standard deviations are of about the same magnitude as the means, so short-term averages fluctuate considerably.

The average length of surgery generated by simulation, seems to be about 4-7% low compared to empirical data. However, the surgery duration in the model is also based on age groups which are divided according to sex. These groups are defined from large samples. The length-of-surgery validation sample is relatively small. As a result, differences between observations and simulated results might well be attributed to the different proportions of patients in the different age groups. This idea is supported by the fact that simulation values are well within the range of empirical averages of the groups.

In addition, day-to-day examinations of the flow through the Medical area were carried out for two four-week periods. Depending on the number of beds left from the night before, the number of patients returning from off-service beds, and the number of "morning" emergencies, the number of scheduled admissions could be verified. Then the remaining number of emergencies could be checked against the total number of off-service placements. The model performs as intended.

9.3 Validation

This section discusses the reasons for considering the model to be a potentially useful administrative tool. The ultimate question is: How well does the model represent reality? In this section, remember that only the Medicine, EENT, and Orthopedic services are presently implemented in the model.

The data used to determine arrival rates, LOS, and length-of-surgery all came from large or carefully selected samples. These data are from 1974, though, and several significant changes have occurred since then. The advent of Day Care surgery has had an impact in reducing the number of scheduled in-patient surgical cases and, by handling some of the shorter cases, has altered both LOS and length-of-surgery patterns. The removal of the Pediatric service and the improved handling of placement for further care (outside of St. Paul's) have also changed the system somewhat. The latter improvement may be particularly significant in its effect on LOS (see Section 12.1). New data-sets for all three of these variables would be desirable.

Next, consider the utilization of the bed areas. In the Medical area, occupancy is very high - close to 100%. In the model it averaged about 99.5%, dropping below 99% for only one three-month average in four years during a period when discharges were extremely high. The EENT and Orthopedic areas are usually not filled with their own patients, but typical week-day occupancy is still near capacity due to off-service patients. In the model, the excess Medical patients served this purpose, and occupancy averaged about 92% in the EENT area and 95% in the Orthopedic area. This is below capacity partially due to the effect of weekends and partially due to the fact that in the actual hospital, off-service patients come from several services, not just one. (In the simulation, surgical area utilization dropped significantly when off-service placement of Medical patients was low due to extra discharges or fewer emergency arrivals.)

The high number of Medical emergency patients, far beyond the Medical area capacity, also causes the Medical waiting list to require careful attention. As the result described in Section 10.1 demonstrates, if the control of this queue is left independent of queue length and hospital occupancy factors, the queue length fluctuates wildly. Since no such extreme fluctuations are apparent in the hospital, it is assumed that several factors interact to control the waiting list there. If the line is getting long, the Admitting Office staff will probably make an extra effort to admit more patients. If it is short they can relax a bit. These variations may be effected by forcing more or less of the Medical emergency admissions off-service. Actually, about half of the Medical admission booking forms specifically request "teaching beds". Since the teaching residents exert most of the control over who fills their beds and how long they stay, (see Section 5.2.5), they may well be the ones who respond to increased or decreased pressure to admit. In addition, physicians may notice the length of the queue and act accordingly in their advice to potential elective admissions.

One further explanatory note is in order. The length of the queue was determined by counting the number of forms in the file box. In some cases a scheduled patient may be admitted by direct communication between the admitting physician and a resident without ever generating a form. Also, for particularly urgent cases there is a slight possibility that the form might be "at the desk" until the patient is admitted (as long as a couple of days), and might not be observed by an outsider looking through the file box.

The empirical data appear as follows. In a three-week collection period the length of the queue averaged 28.7 with a small standard deviation of 1.4. A later observation revealed 36 waiting. In each case, there was a large number of long-wait patients. Many of these are expected to have cancelled and never to have been admitted. In fact, at the start of the three-week sample, there were seventeen patients who had waited over one week. After the three weeks, five of these had cancelled ... none had been admitted! Furthermore, the slight variation in the sample may be attributable to the fact that only one third of the average volume of requests appeared during those three weeks. It is felt that, of the hospital queue observed to range from 26-36, some portion - say maybe 20% - will probably cancel and are not, in fact, "active" queue members. A four-week test on the model yielded a 23.2 average and 1.5 standard deviation which is highly acceptable. The three-month averages over four years themselves average 23.4, with 80% of the values lying within four of this number. This set of averages and the four-week averages for one year are graphed at the end of this chapter. (Figures 9.1 - 9.3 and 9.7 - 9.9 relate to the length of the Medical queue, which is the variable shown in Figures 9.4 and 9.10.)

The waiting-time distribution for Medical patients is another matter. The data sample was very small, but the average was 5.2 days, and was almost identical for all three schedulable patient categories. Although the Admitting Office clerks attempt to give higher priority to the urgent and semi-urgent categories, the sample showed no difference (over three-quarters of those admitted were teaching patients). Thus, instead of ordering the <u>entire</u> waiting list by category, the only use made of the category of a Medical patient was to determine the sequence in which to file <u>each day's</u> forms. Furthermore, since no programmable algorithm could be distinguished in the selection of patients to be admitted, the model has a basically FIFO queue for its Medical patients. Postponement (which increases the variance of the waiting time distribution) was not implemented in the model due to a lack of accurate data. Hence, a Medical patient in the model has an average waiting time of about 6.3 days (probably reasonable) with slight variations. A cross-section of waits at any instant would show some patients with one day waits, some with two, some with three, and so on up to whatever the current maximum might be (no more than fourteen days in the one-year run). The actual list has a cross-section spreading from one day to as much as five months (in the case of one "urgent teaching patient" noticed)!

The modelling situation seems even better for the surgical queue. Deviations from reality in the simulation, particularly in the pattern of patients slated any given number of weeks in advance, may be attributable to differences in the 1974 data and 1976 practice. In 1974, there was no Day Care surgery, and it seems that up to five scheduled procedures for Orthopedics and nine for EENT were allowed per day (in contrast to four and six now). The model observes the 1974 limits and patient arrival rates.

Because of the scheduling mechanism explained in Chapters 7 and 8, the surgical queue is quite stable. The three-month averages over four years themselves averaged 111.4, with three-quarters of these values less than 5.5 away. About two-thirds of this queue is made up of EENT patients. The one sampled value of 136 (96 EENT, 40 Orthopedics) is well within the range of the simulation's queue length despite its stability. As suggested above, the simulation's distribution of the number of patients slated for a given number of weeks away does not quite "fit" the sample distribution, but appears reasonable. Greater accuracy would require a thorough examination of scheduling rules.

As suggested by the time stream sequence of Figure 8.1, the critical number of Medical patients transferred to the wrong area is the product of several interacting variables each of which may fluctuate (Medical discharges, Medical area returnees, morning and other emergencies, length of the waiting line). Only one data value, the year's total for 1976, is currently available (see Appendix 2.1). It suggests that at the model's level of Medical admissions, a rate of 1460 placed off-service per year is excellent. The simulation suggests that this variable is quite sensitive to fluctuations in the variables which determine its level. Nevertheless, its average over four years is 1455! The values for four years and one year are graphed at the end of this chapter (Figures 9.5 and 9.11).

The number of "No Beds" for EENT and Orthopedics is difficult to determine, since only the daily total for all services has been recorded. This varied greatly in 1974, with an average of 39 per month, but as high as twenty in one day! The average in 1976 was 31 per month. It is not clear whether the improvement is random or a result of greater care in patient placement and transfers. If the proportion of "No Beds" is identical to the proportion of procedures, EENT and Orthopedics may expect 115 per year (at the 1976 rate). The model has an average over four years of about 117! The constraints in effect are: the level to which off-service patients may fill beds before causing transfers and the level to which morning emergencies of the proper area (and other areas) are allowed to take off-service beds before being placed elsewhere. Figures 9.6 and 9.12 show "No Bed" numbers.

The final validation item used was the number of patients slated for surgery. For Orthopedics, this averaged about 4 in the model. 1974 data suggested 4.5. The distribution for the model was correspondingly low. For EENT the model gave 5.7 per day. Real data gave 6.7, but on a small sample. These differences may well be attributable to block booking by "composite physician" and not allowing anyone else to fill his day with any but urgent patients or in-hospital patients. Particularly in the Orthopedic service, for which each of four days has two physicians booked and the other has only one, this may be a factor.

As these comments on validation indicate, the model behaves very satisfactorily, particularly for simulation over the long-term. Since a complete range of validation data is not available, and the accuracy of different variables is not well known, nor is the sensitivity of the system to their changes, I do not feel that a quantification of the precision of the model in terms such as "accurate to within ..." would be meaningful.

To summarize, the results obtained for all of the critical variables, incuding some which are the result of several interacting forces, suggest that the model structure is good.

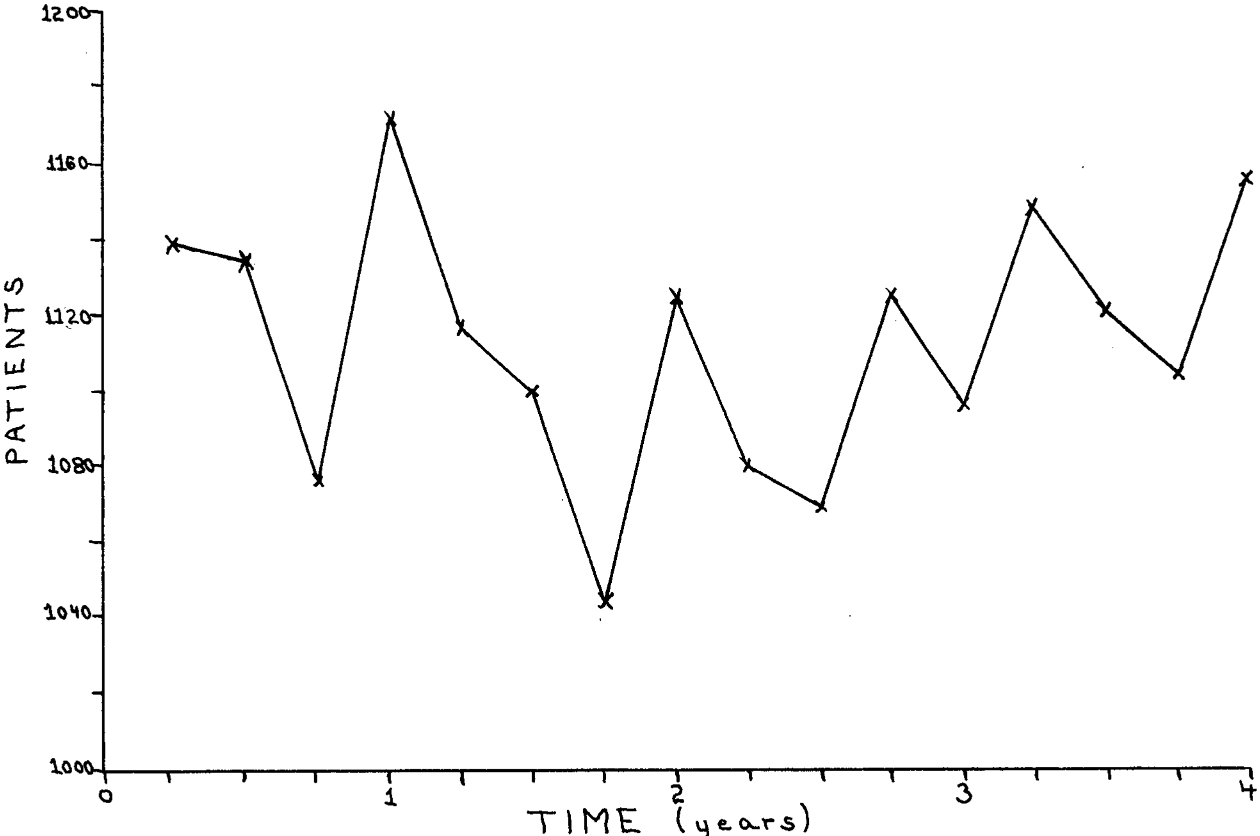

Fig. 9.1 Medical "immediate" patients (per 3 months) as a function of time

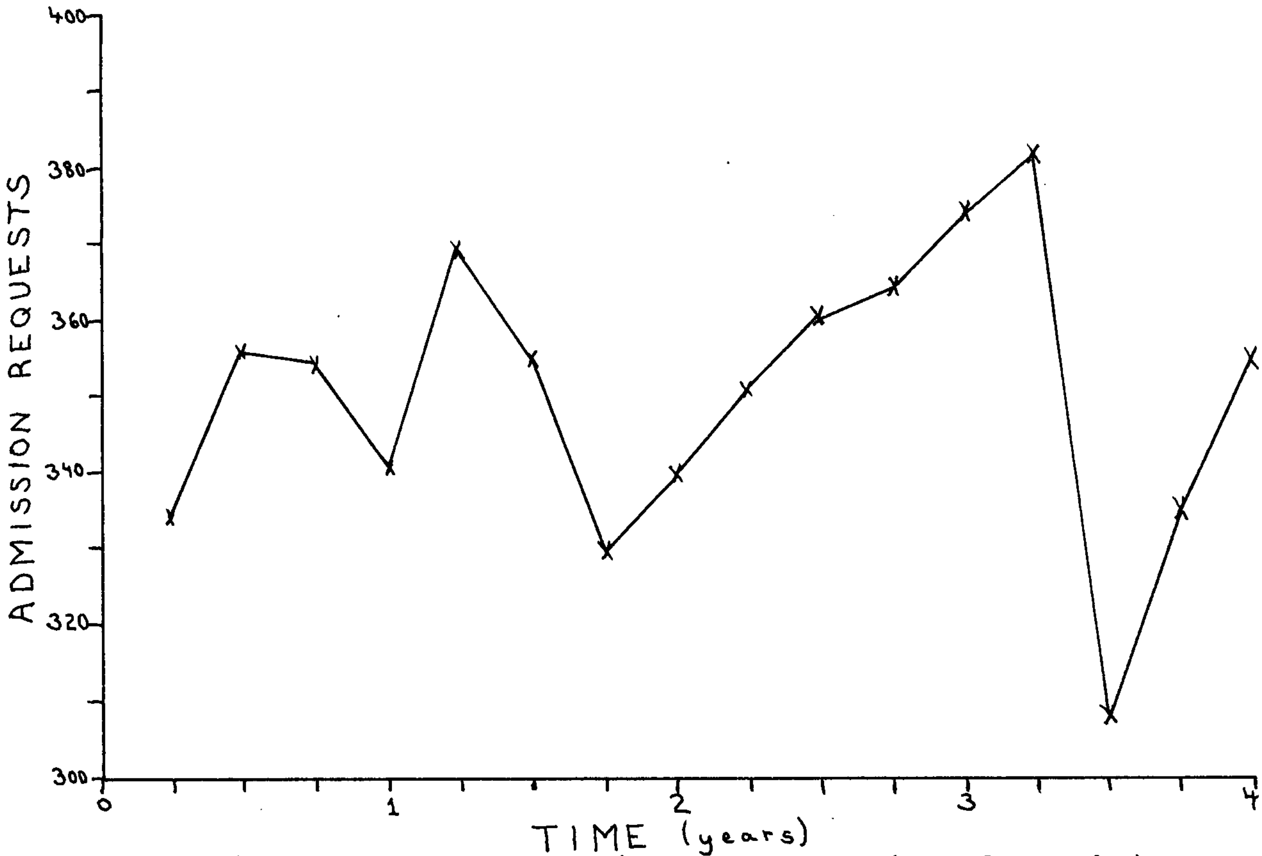

Fig. 9.2 Medical schedulable patient requests (per 3 months) as a function of time

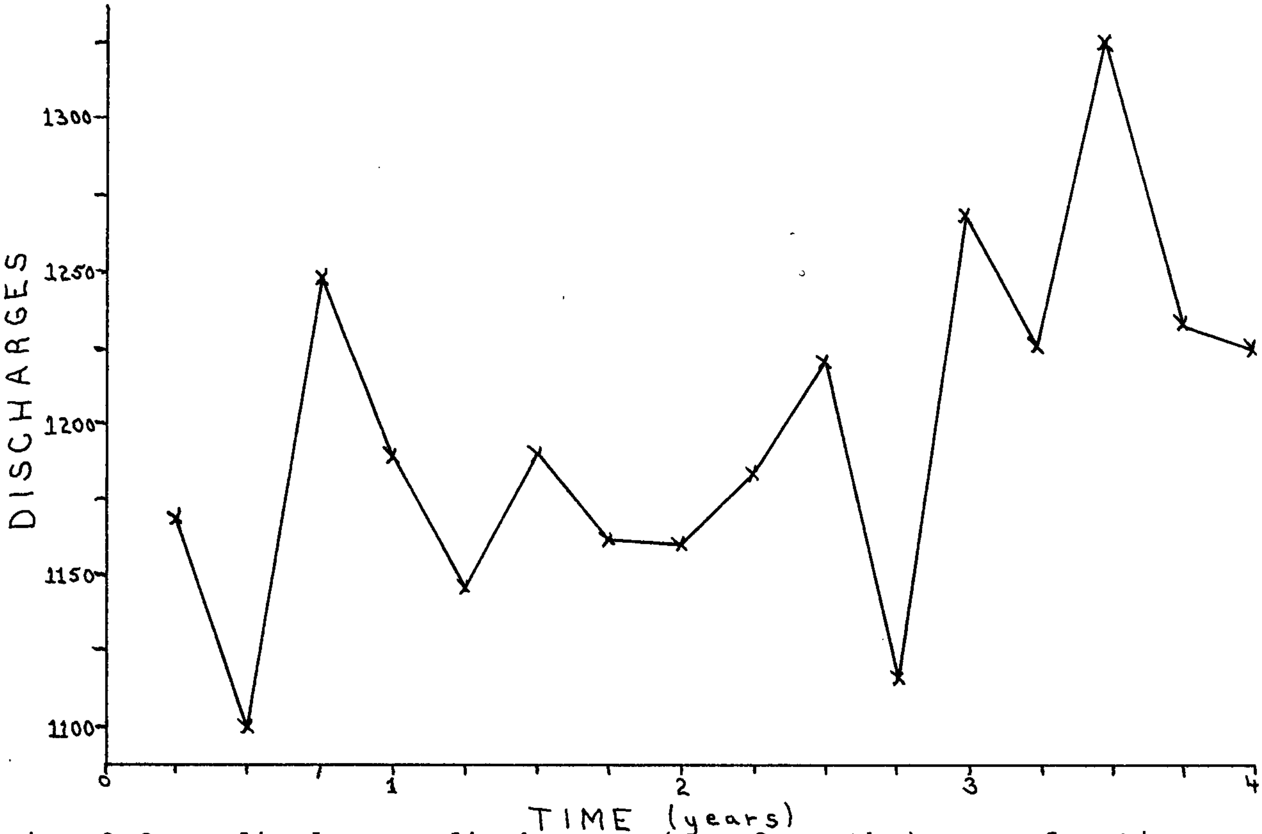

Fig. 9.3 Medical area discharges (per 3 months) as a function of time

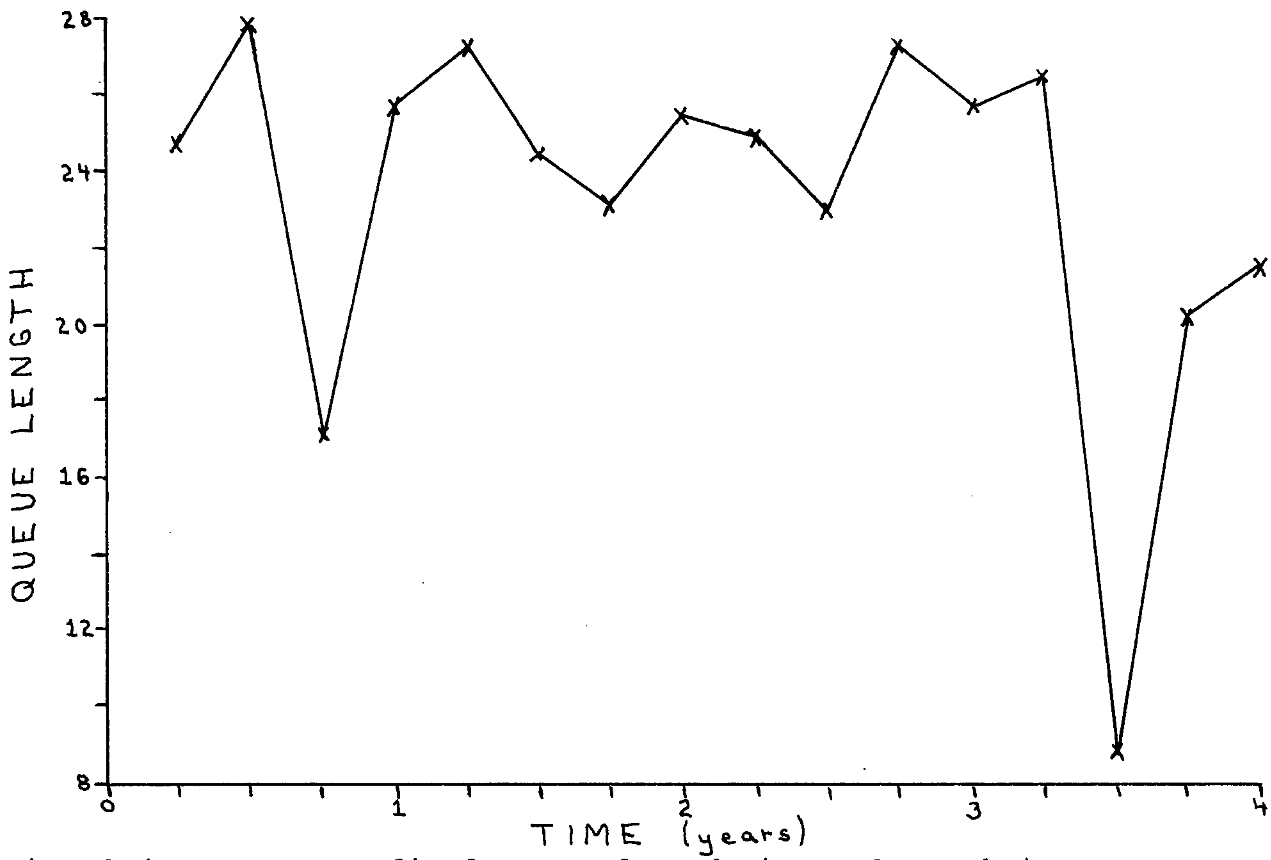

Fig. 9.4 Average Medical queue length (over 3 months) as a function of time

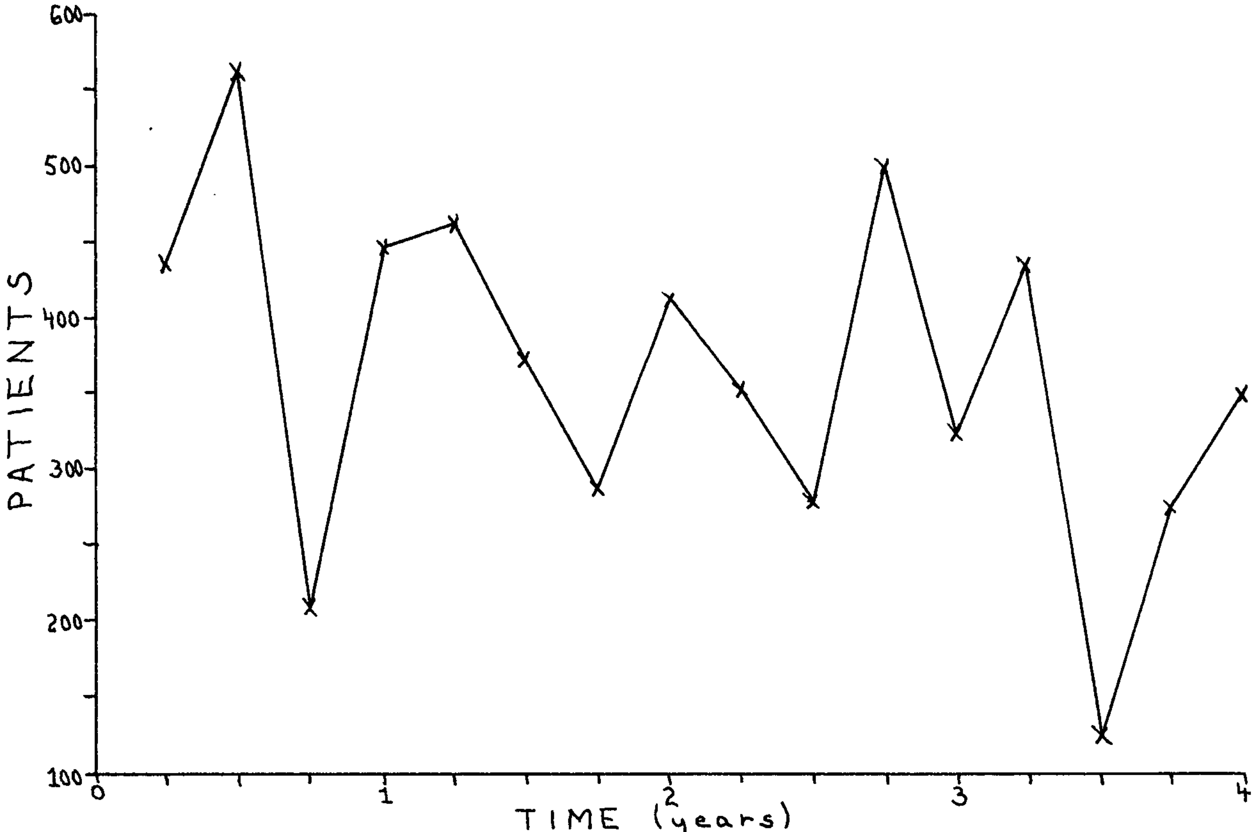

Fig. 9.5 Medical patients placed off-service (per 3 months) as a function of time

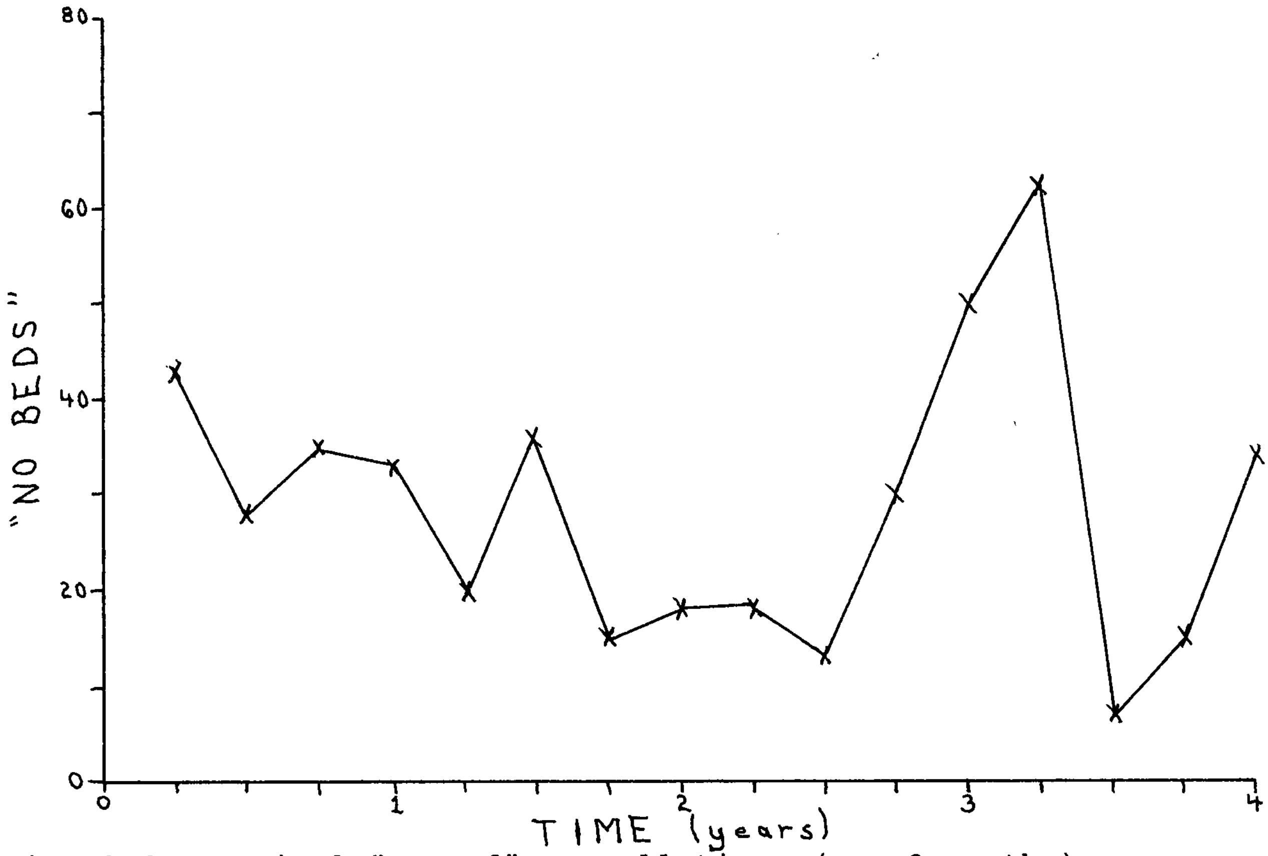

Fig. 9.6 Surgical "No Bed" cancellations (per 3 months) as a function of time

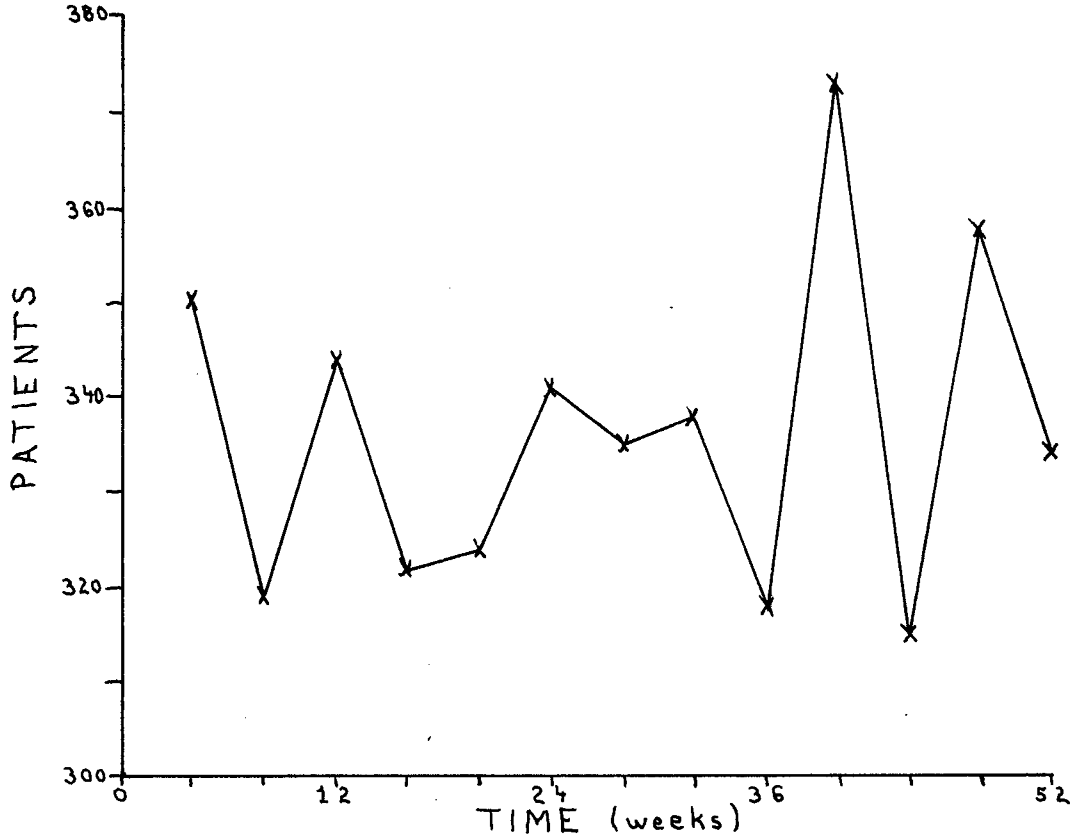

Fig. 9.7 Medical "immediate" patients (per 4 weeks) as a function of time

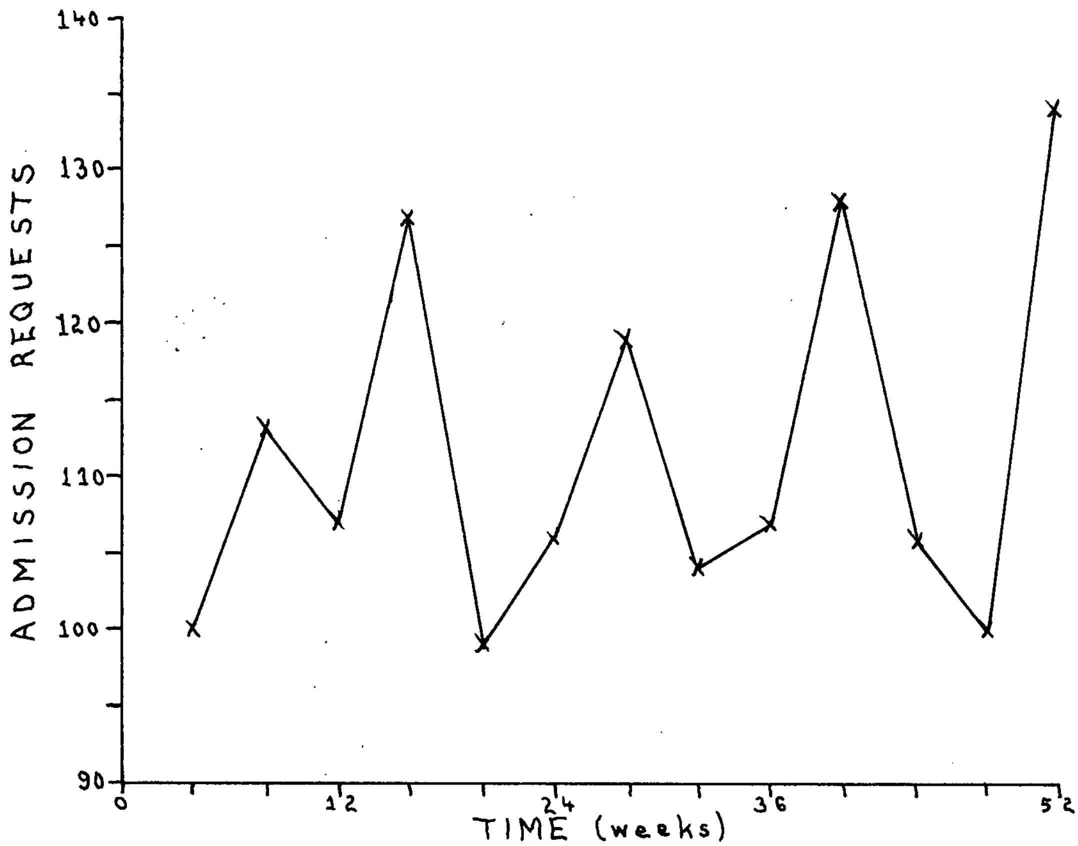

Fig. 9.8 Medical schedulable patient requests (per 4 weeks) as a function of time

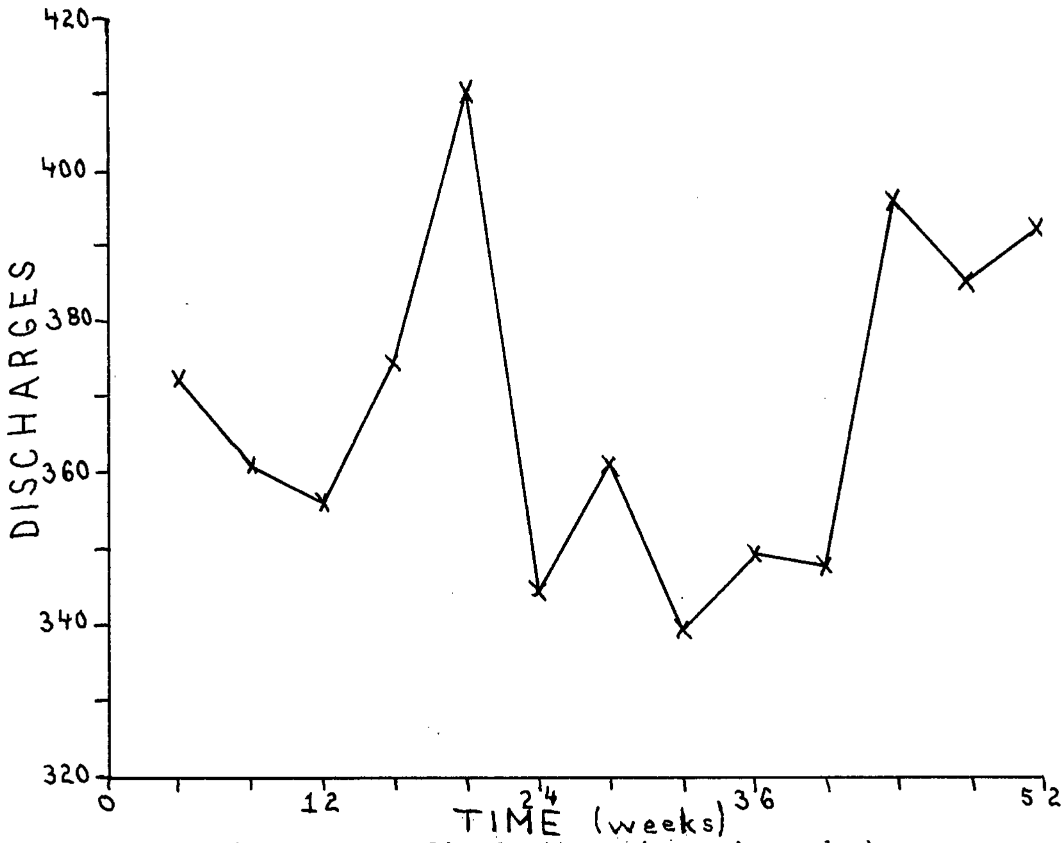

Fig. 9.9 Medical area discharges (per 4 weeks) as a function of time

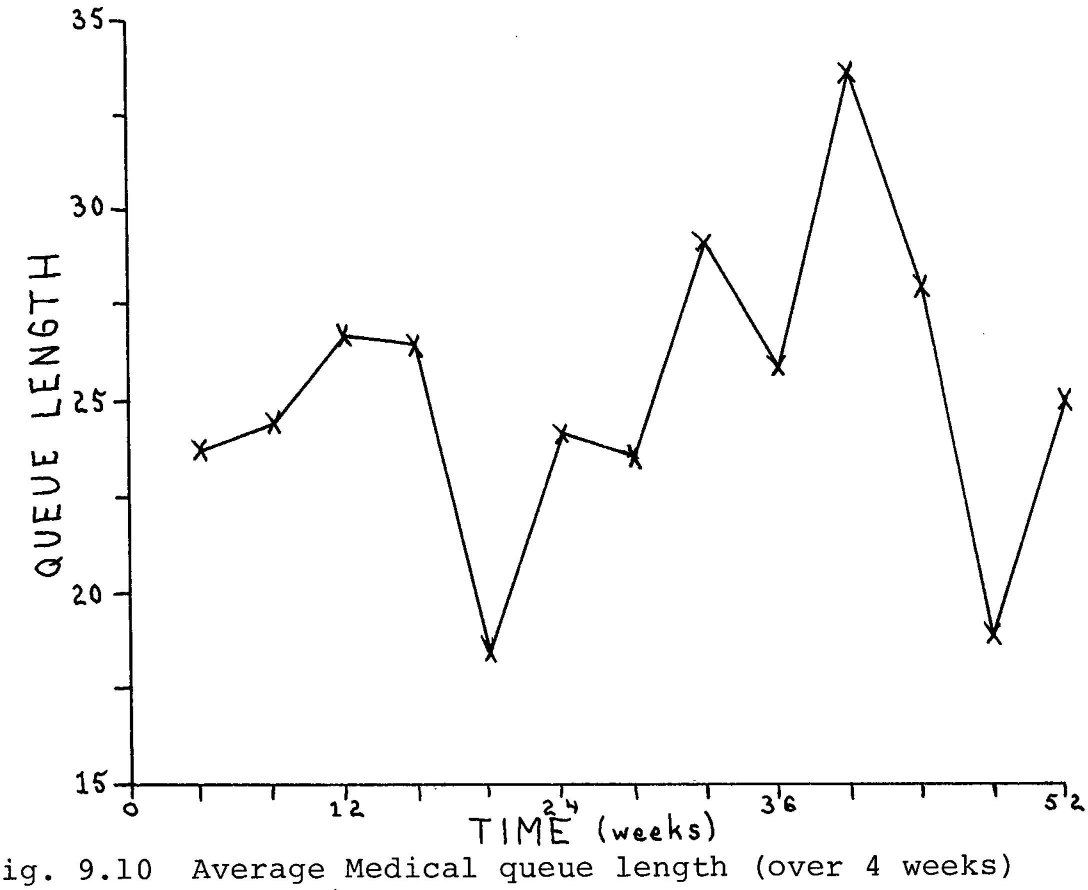

Fig. 9.10 Average Medical queue length (over 4 weeks) as a function of time

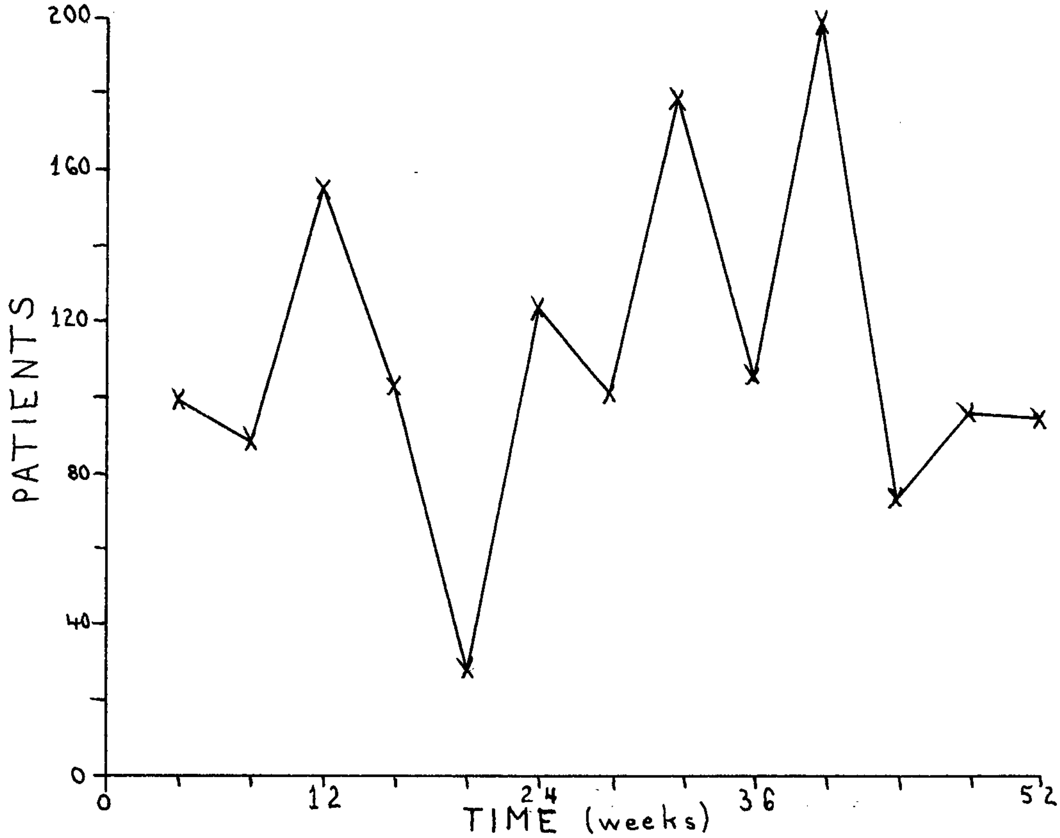

Fig. 9.11 Medical patients placed off-service (per 4 weeks) as a function of time

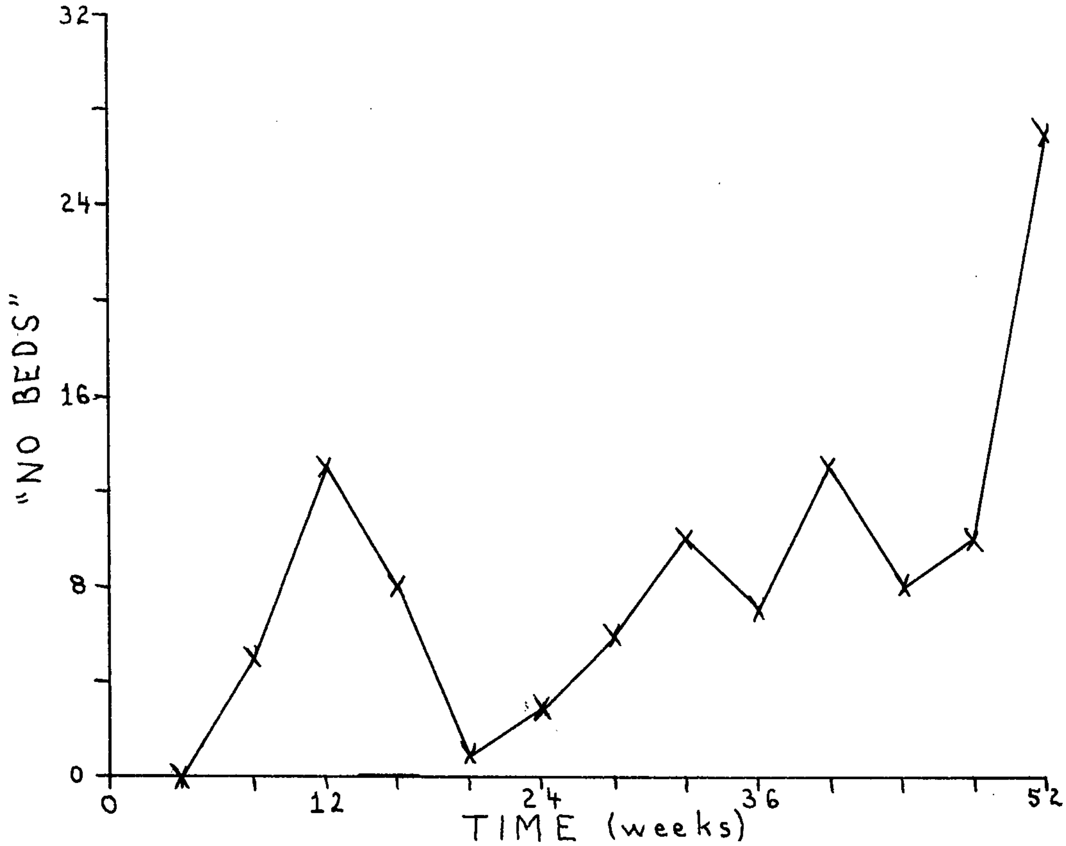

Fig. 9.12 Surgical "No Bed" cancellations (per 4 weeks) as a function of time

CHAPTER 10 EXPERIMENTS

Several experiments were performed with the validated and verified model. These particular experiments were selected in order to demonstrate some of the changes in the St. Paul's Hospital admissions and scheduling system which the model might be used to investigate. In addition to these experiments, one result which appeared during the development of the model is included in this chapter because of its significance.

The experiments were tested over the same one-year period discussed earlier. Unless deliberately altered, then, the sequence of patients and their lengths-of-stay are identical. However, in the experiments for which the sequence of patients arriving has been altered (Sections 10.5 and 10.6), it has been noted that the experimental results are within the range of the random variations in the original run. In order to draw any firm conclusions, it would be advantageous to run such experiments for at least two years and preferably four.

10.1 Admission Strategy

In the course of "tuning" the model, it became clear that the fluctuation in the length of the Medical queue is extremely sensitive to the admission strategy employed. In the present model after "tuning", the number of patients to admit is determined from both the number of beds available and the length of the Medical queue. An earlier preliminary version of the model admitted patients in a more random fashion. On 50% of the days, admissions were allowed from the Medical queue until there were three beds left. On the other 50% of the days, they were allowed until four beds remained in the Medical area. (These proportions and limits had been found to give the most realistic numbers of "No Beds" and off-service placements.) In an eight-year run, the Medical queue was observed to fluctuate from 0 to 150, with several quarter-year averages over 100! It should be noted that there were three other differences in that early model which would have contributed to the fluctuation. (i) Rather than 20% of the emergency arrivals being allowed to precede the scheduled arrivals and to enter until there were eight beds left, 47.5% of the emergency arrivals were allowed to enter first, until there were six beds left. The fact that the same <u>total</u> number of Medical patients entered suggests that this was not a critical factor. (ii) Rather than having separate arrival processes for immediate and schedulable patients, the earlier model used a single process. This would have increased the variance in the number of Medical patients entering the queue. A later test indicated that the length of the the queue was not particularly sensitive to this variance. (iii) A portion of the scheduled admissions originally postponed and returned to the queue. This should have altered the waiting-time distribution without significantly affecting the length of the waiting queue.

In conclusion, the length of the Medical queue was a critical variable observed while adjusting the model. Indications are that the number of admissions from the queue must be carefully controlled rather than left random, if the length is not to be allowed to fluctuate considerably.

10.2 Bed Allocation

In the one-year run of the final model, it was observed that there was an average of about seven Medical patients in Orthopedic beds, eight in EENT beds, and thirteen in "overflow" beds. As a result, it was decided to reallocate the number of beds per service area. The Orthopedic area was given four less beds, the EENT area five less, and the Medical area sixteen more.

Several other alterations were necessary to correspond to this reallocation. The bed limits for "morning" emergency admissions were revised. The number of units of "remaining capacity" which would permit the admission of certain numbers of Medical schedulable patients was redefined and the pattern was altered slightly. Furthermore, since there were less beds in the surgical areas, restrictions were tightened on the number of off-service patients to be allowed without necessitating a transfer.

The response of the system was as follows. Eight weeks were allowed for the system to restabilize. The average length of the Medical queue decreased by three while the standard deviation increased from 4.1 to 5.8 (see Figure 10.1). The number of "overflow" beds which was required dropped by an average of 4.1. The utilization of the smaller EENT area was even down slightly. The number of Medical patients who were transferred off-service dropped from 1261 (in 44 weeks) to 707, but fluctuated almost as greatly as before. The number of "No Beds" increased from 106 to 161 over the same time period (see Figure 10.2).

The system became considerably more sensitive to variations in the random influences on it. With less surgical beds, the "No Bed" variable showed much more sensitivity to changes in the number of Medical patients off-service and in the arrival rates of surgical patients. It is significant that although the net number of non-"overflow" beds was increased by 7, the average number of "overflow" beds in use dropped by only 4.1. (The number of Medical patients off-service dropped by more than fifteen with the sixteen extra beds, but the surgical patients had to use additional overflow beds.)

In view of the increased total bed usage and the large increase in "No Beds", this alteration does not appear to be advisable.

10.3 Combining Bed Areas

An experiment was done to combine the EENT and Orthopedic bed areas. Patients of both services used a single bed "pool", which was given as many beds as the two areas together had originally been allocated. Any relevant limits were changed to

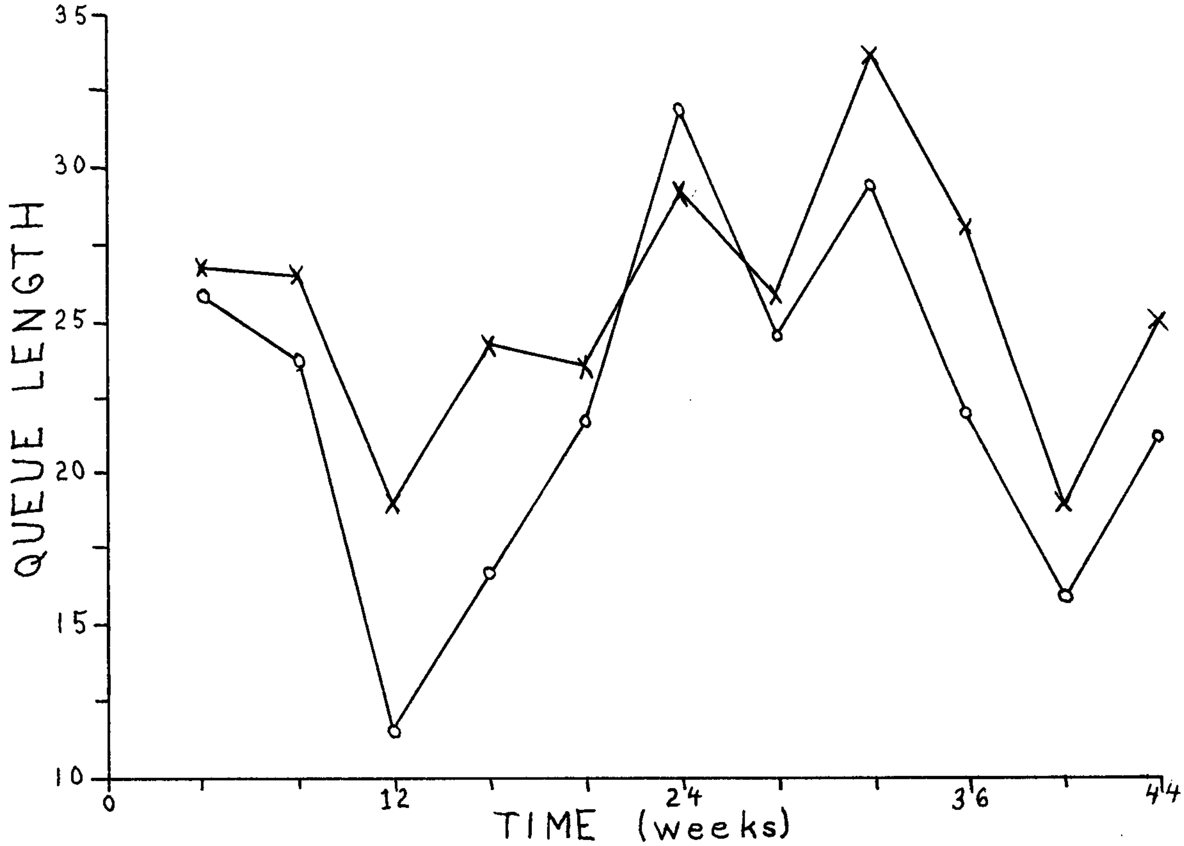

Fig. 10.1 Average Medical queue length (over 4 weeks) as a function of time : Original x ; Experiment o

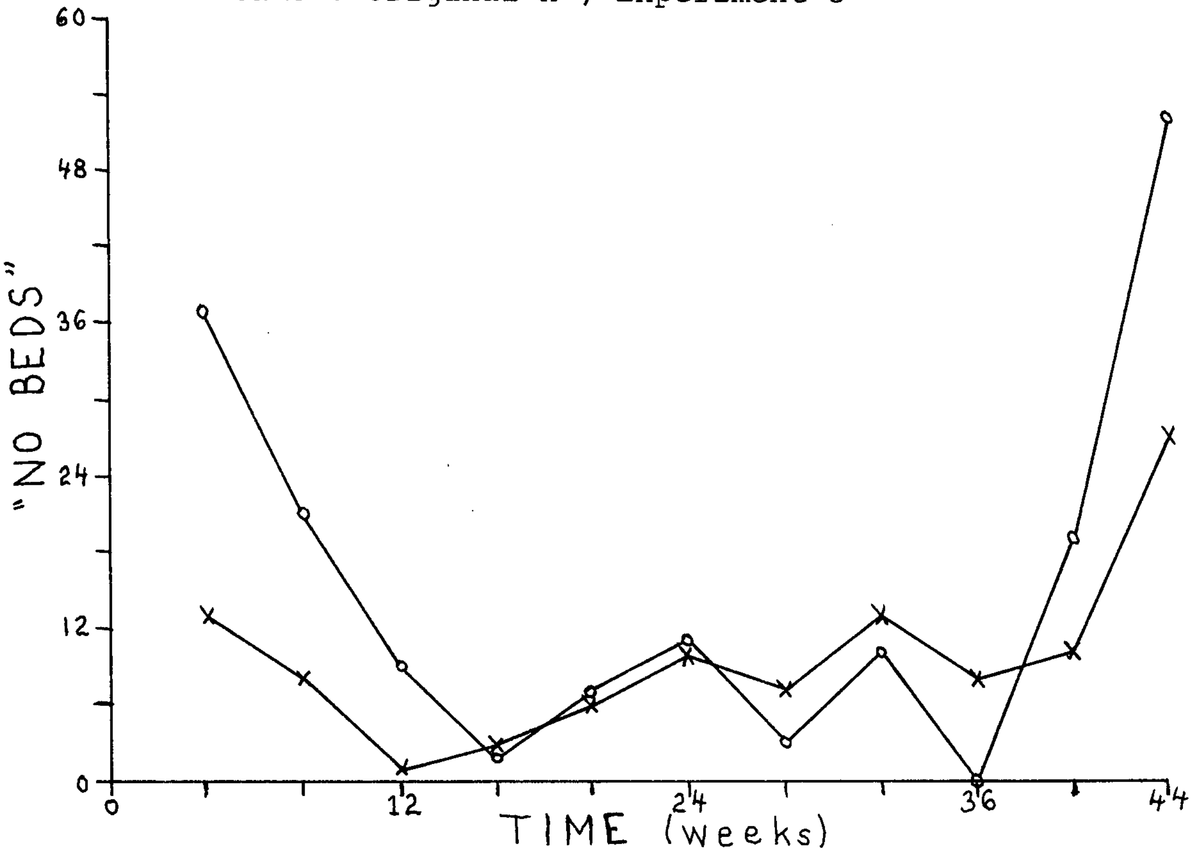

Fig. 10.2 Surgical "No Bed" cancellations (per 4 weeks) as a function of time : Original x ; Experiment o

the sums of the previous limits. Of the one-year run, eight weeks were allowed for the model to restabilize, and the last 44 weeks were compared.

The results were interesting. The surgical queue length exhibited a pattern similar to the original one. The utilization of the new bed "pool" was about the same as the weighted average of the previous areas. However, the number of "No Beds" dropped significantly from 106 to 46 (see Figure 10.3)! The number of Medical patients who were sent off-service dropped by 120, as a result of the number of patients returning to the Medical area dropping by 90. The only adverse reaction was that an average of 4.1 more overflow beds were required (see Figure 10.4). Further tests which altered off-service limits failed to reduce this number.

These results may be explained as follows. The surgical areas together had more flexibility in bed use than either had separately. If a surgical patient needed a bed, he was more likely to find it in the combined area than he would have been in his own area. As a result, there were less "No Bed" cancellations, and less Medical patients were allowed into the combined area. This forced more Medical patients to the "overflow" area. In addition, surgical emergency patients who could not find a bed in the combined area had to go to the "overflow" area.

Of course, these results offer only the numerical aspects to be considered regarding such an alteration. The quotation from Goldman et al (1968) which was included in Chapter 3

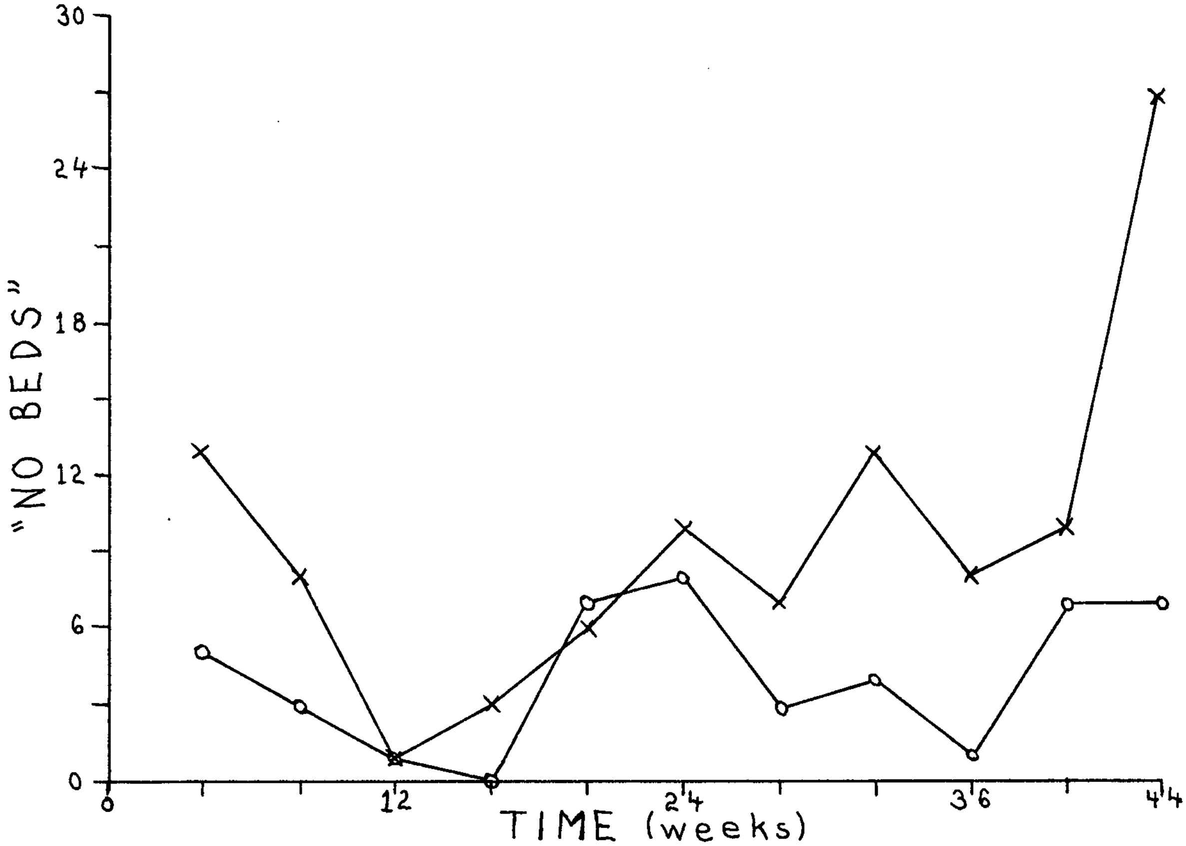

Fig. 10.3 Surgical "No Bed" cancellations (per 4 weeks) as a function of time : Original x ; Experiment o

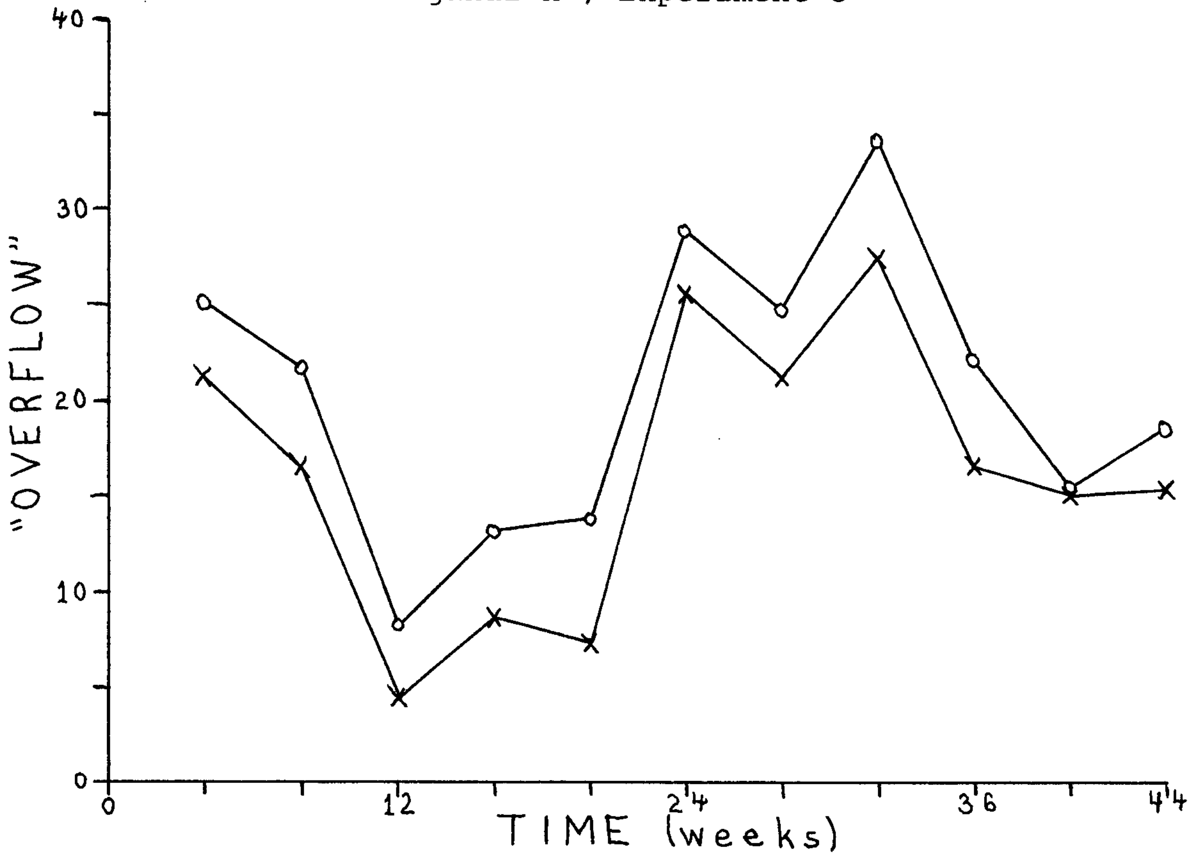

Fig. 10.4 Average use of "overflow" beds (over 4 weeks) as a function of time : Original x ; Experiment o

explains why a beds-to-service allocation is advantageous. If the administration considers the "No Bed" variable to be particularly important, and if extra beds can be arranged elsewhere, then the administration should consider a removal of the distinction between beds of different service areas.

10.4 Requests for Specific Surgery Dates

It was observed from the data collected that a large number of the physicians requested particular dates on their surgical admission forms. The question arises: What if the physicians left more of the dates up to the booking clerk? Of course, some of the requests came from patients and were transmitted by their physicians. However, on some occasions, the physician could probably have let the booking clerk choose the date. An experiment was done to test what would happen if physicians had only specified half as many dates as they actually asked for. The distribution of these dates was not altered.

The length of the surgical queue dropped significantly with a similar drop in surgical waiting time. Eleven more Orthopedic patients and thirty more EENT patients were admitted that year. The numbers of operations which were performed each month fluctuated, but the average was the same for Orthopedics and only one more per month for EENT. No other variables changed significantly. Figures 10.5 - 10.7 show the comparative numbers of EENT procedures, numbers of Orthopedic procedures and surgical queue lengths.

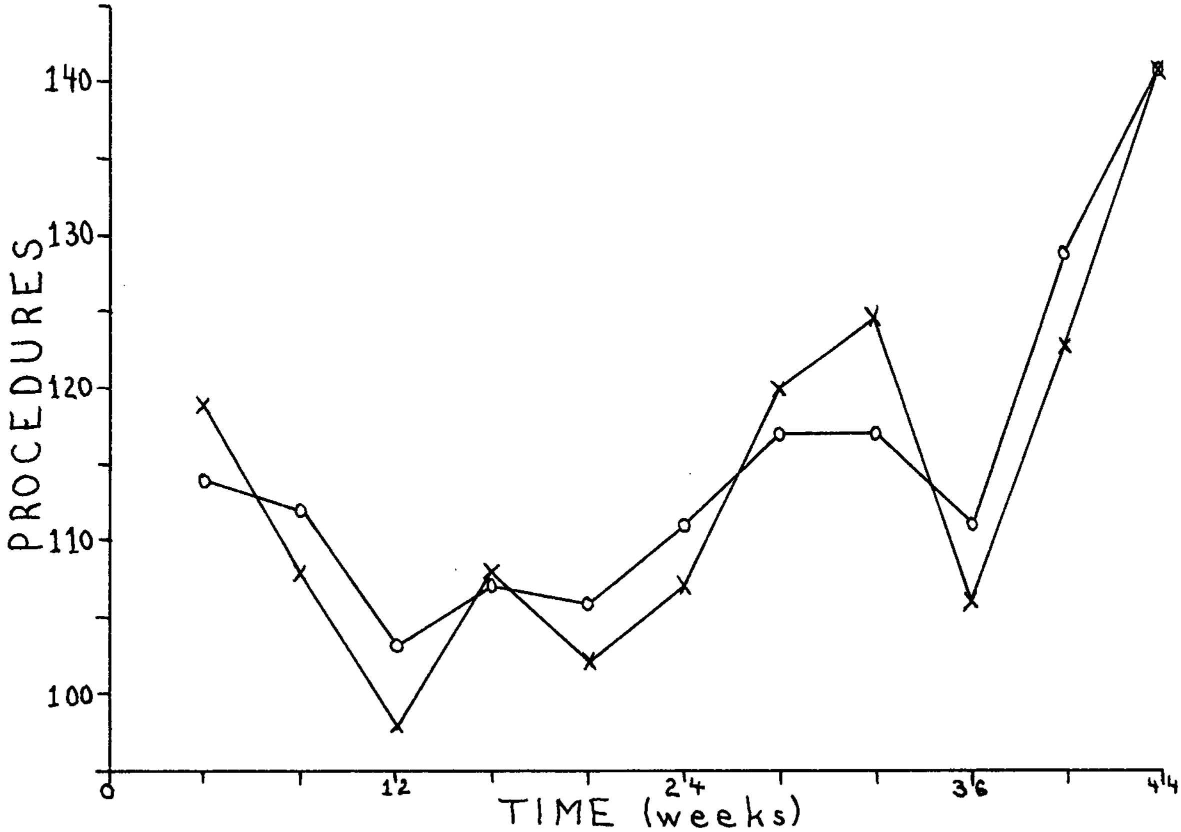

Fig. 10.5 EENT surgical procedures (per 4 weeks) as a function of time : Original x ; Experiment o

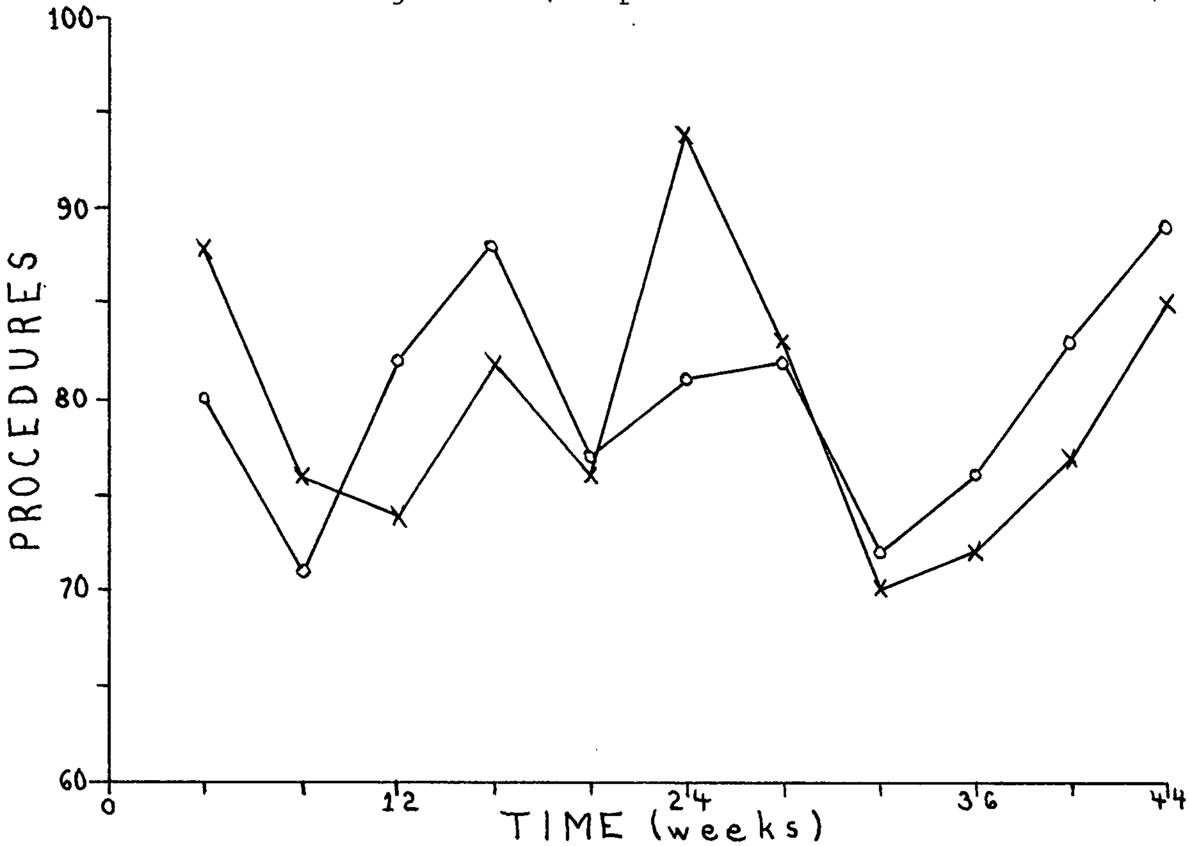

Fig. 10.6 Orthopedic surgical procedures (per 4 weeks) as a function of time : Original x ; Experiment o

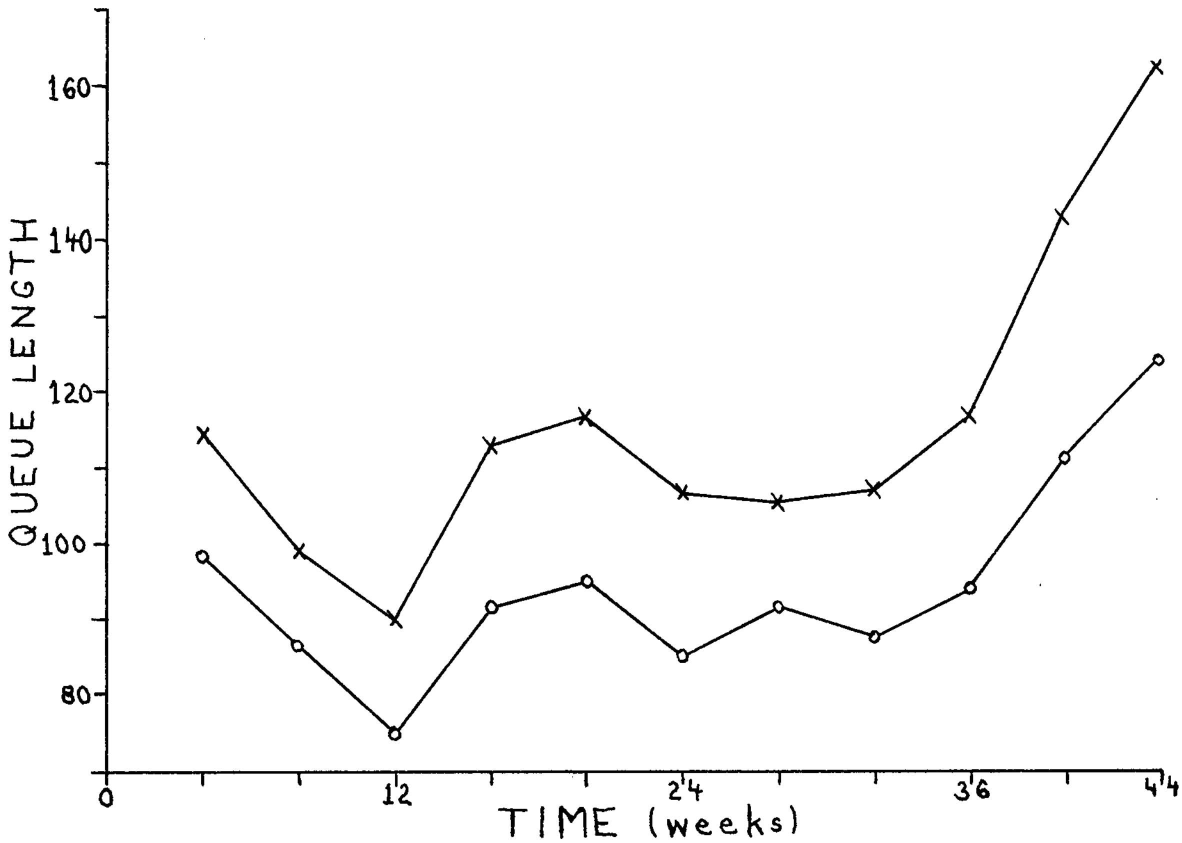

Fig. 10.7 Average surgical queue length (over 4 weeks) as a function of time : Original x ; Experiment o

The real gain seems to be in the waiting time of surgical patients. As mentioned earlier, the physicians probably do a better job of selecting days than the model does, since the physicians should be able to tell when they are free, while the model selects days at random. As a result, this experiment may only indicate a change that could be made to improve the model. However, it does point out the fact that _if_ a physician is selecting his requested surgical dates in a haphazard fashion, or if he is choosing his dates far enough in the future that he expects them to be available, he would probably do better to leave it up to the booking clerk.

10.5 Classification of Patients

It has been suggested that not every patient who arrives at the St. Paul's Emergency Unit should be there. Some of the patients could possibly be handled on a schedulable basis. With this in mind, the arrival patterns of Medical patients were altered so that 365 of the immediate patients were re-classified as schedulable (one per day). No other model parameters were changed.

The results were rather inconclusive. The average length of the Medical queue did rise by about 4.5, but the average waiting time dropped slightly. The total number of Medical patients placed off-service was the same, although the number in each four-week time period stabilized (see Figure 10.8). This stabilization was reflected in a somewhat lower variance for the surgical queue. The number of "No Beds", however, increased from 111 to 130 (see Figure 10.9). The previous 4-year run had reached as many as 139 "No Beds" in one year, so this result may be a random response to the other fluctuations. However, since it is probably not, the result is disturbing.

In any case, it seems from the standpoint of handling the "No Bed" problem, that the administration does not need to concern itself with encouraging Medical physicians to decrease their use of the Emergency Unit. The problem seems to be a result of the number of total Medical patients, not necessarily of the high proportion of emergency patients in that service.

10.6 Number of Patients

One of the most obvious changes to be investigated by the model is in the arrival rate of patients. The final experiment increased the number of Orthopedic patients by "about 10%". (It turned out to be 13.4% on the one-year runs compared) and added one more Orthopedic surgeon, which reduced the slating irregularity by making an even number of ten surgeons. Correspondingly, the numbers of beds reserved in the Orthopedic area were changed, as were the allowable limits before transferring out an off-service patient.

The length of the surgical queue stabilized somewhat, and increased by an average of about seven. The "overflow" area utilization increased significantly, by an average of about 5.5 beds (see Figure 10.10). The Orthopedic area utilization did

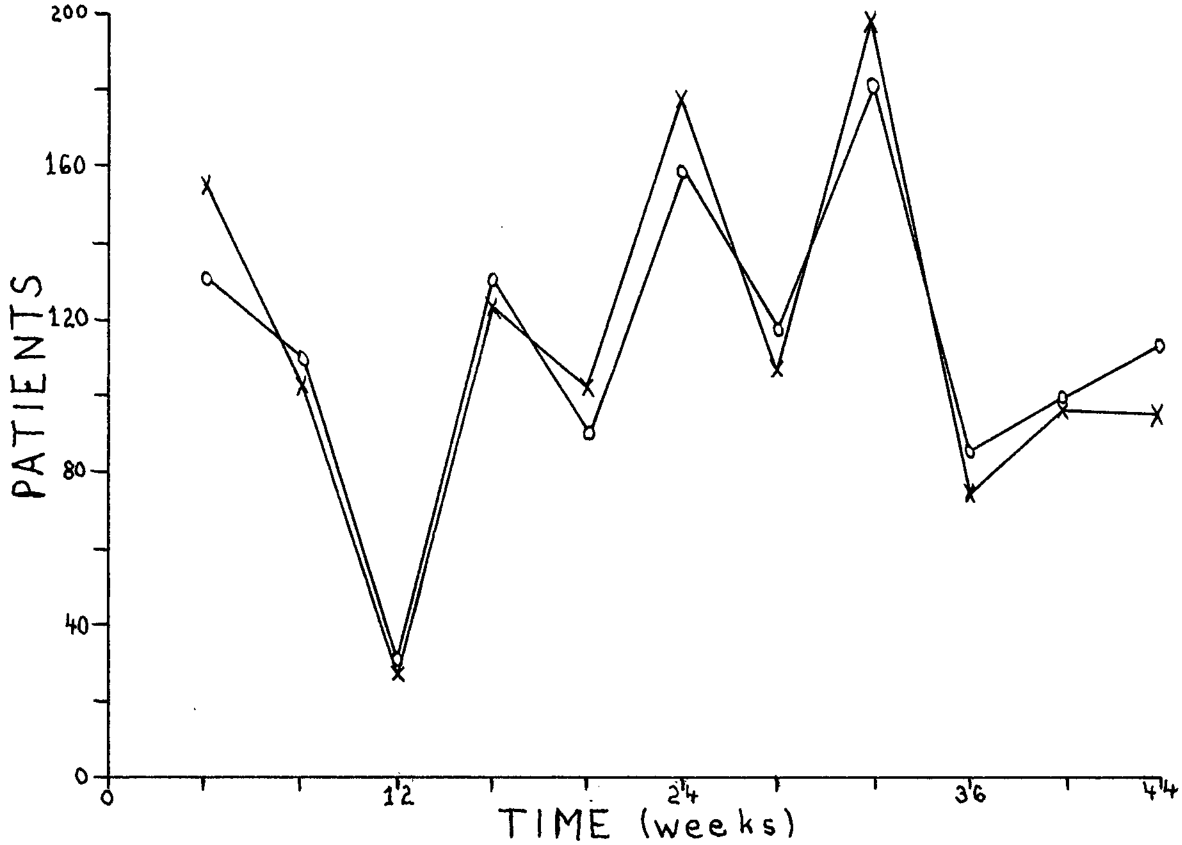

Fig. 10.8 Medical patients placed off-service (per 4 weeks) as a function of time : Original x ; Experiment o

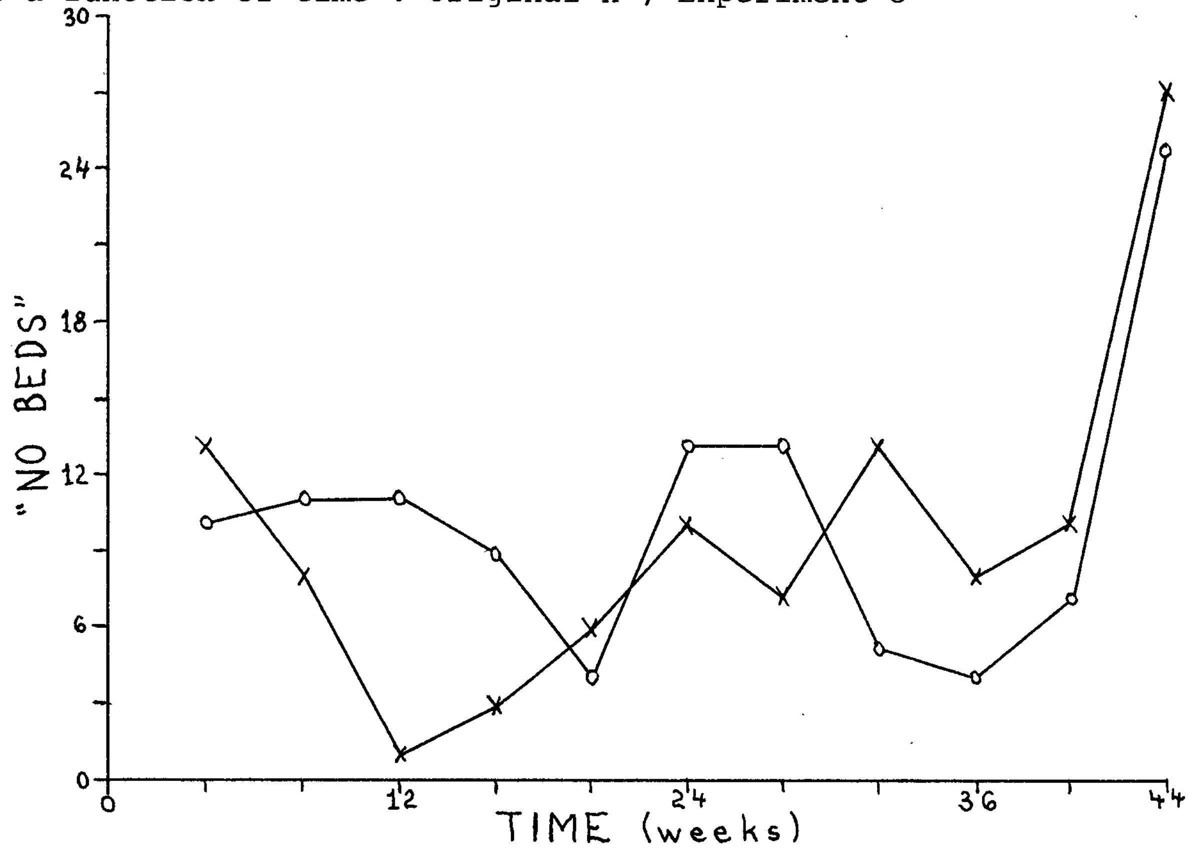

Fig. 10.9 Surgical "No Bed" cancellations (per 4 weeks) as a function of time : Original x ; Experiment o

not change appreciably. The number of patients who were returned to the Medical area increased about 20%, by 93 in 44 weeks. Therefore, the number of Medical patients who were sent off-service increased, by 77. Although transfer limits had to be tightened considerably, the total number of "No Beds" changed only slightly to 107 from 106 and varied less than before (see Figure 10.11). The number of Orthopedic procedures increased by about two per week to compensate for the extra demand. The extra surgeon facilitated this effect. The average wait of Orthopedic patients increased by less than one day.

As mentioned before, the hospital probably does a better job than the model of leveling the use of the Orthopedic slate over all days-of-the-week. The increase of one surgeon in the experiment achieves this same effect to some extent, thereby reducing the impact of the extra patients. Nevertheless, the experiment shows what effect such an increase in Orthopedic patients would probably have on the demand for "overflow" beds and on the number of "No Beds".

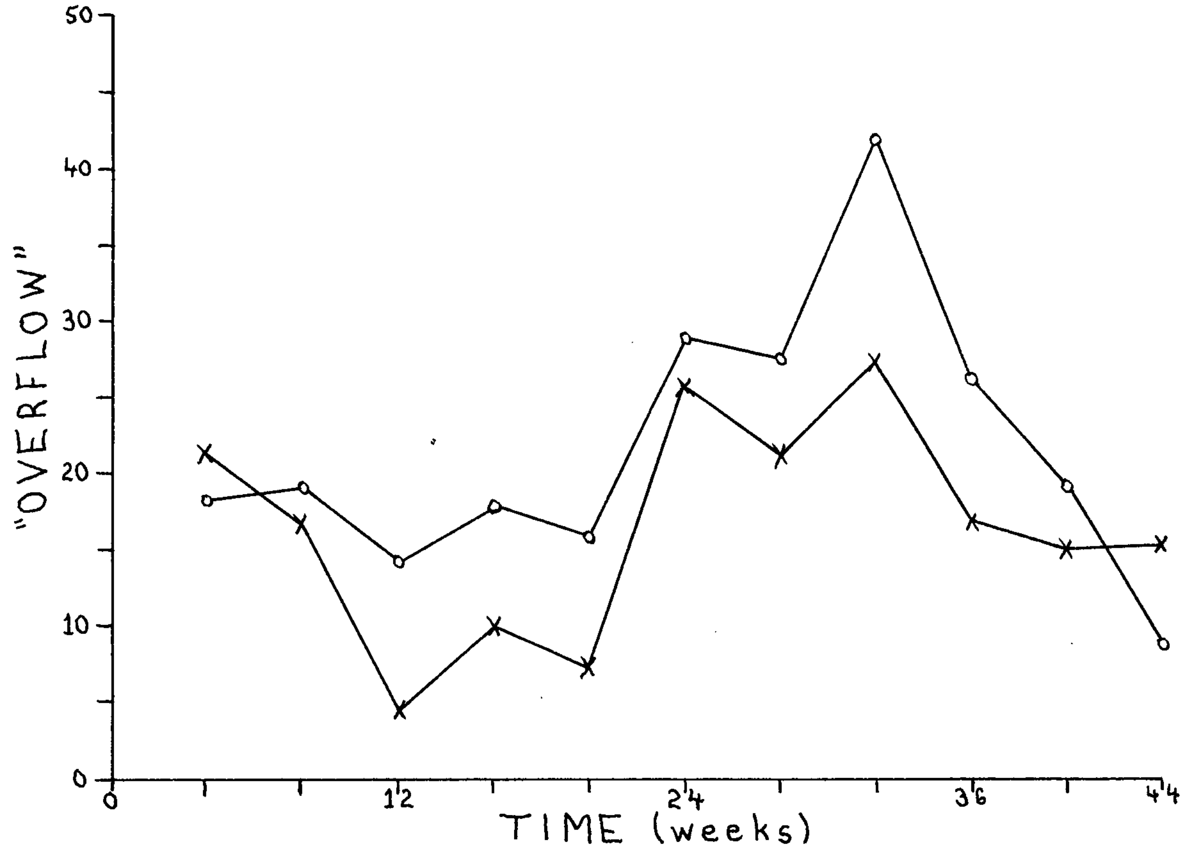

Fig. 10.10 Average use of "overflow" beds (per 4 weeks) as a function of time : Original x ; Experiment o

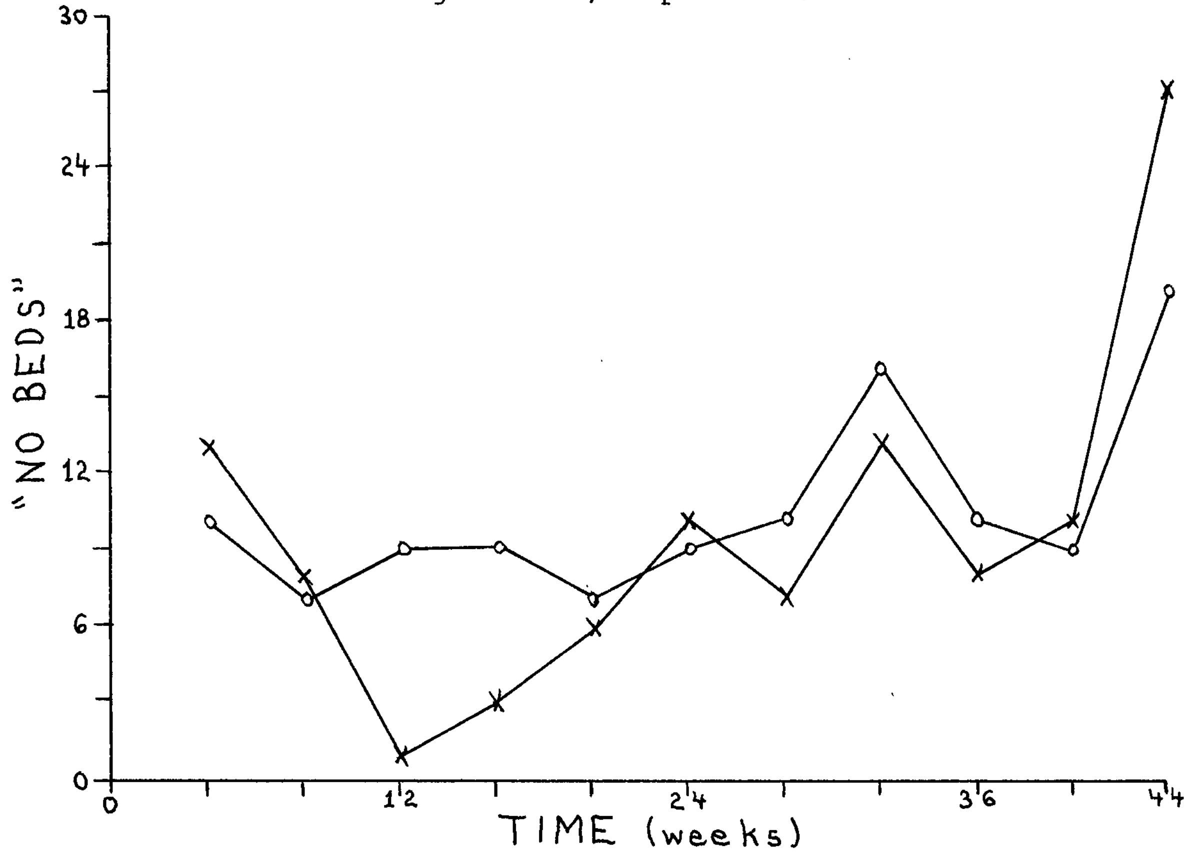

Fig. 10.11 Surgical "No Bed" cancellations (per 4 weeks) as a function of time : Original x ; Experiment o

CHAPTER 11 PROPOSALS FOR FUTURE CONSIDERATION

In this chapter I suggest areas which may be investigated for development, improvement and use of the model. These suggestions are intended to be of assistance in defining the scope of further study and detailing some possibilities.

11.1 Data

Certain data items not previously available are now being collected at St. Paul's. The experience gained in this project suggests improved collection methods for others. In addition, changes in policy or practice at St. Paul's call for updating certain other data. Some further comments appear on Table VIII.

A significant improvement at St. Paul's, from the point of view of studies of this sort, concerns the the amount of data being collected by the Admitting Office. As of 1977, the following items are recorded daily.

(i) Regarding overall admissions:

total number of admissions,

admissions to extended care,

number of "No Beds",

emergency admissions (total, Medical, and surgical),

DU admissions,

admissions to the correct area,

admissions to the wrong area

(ii) By service:

scheduled admissions,

urgent admissions,

admissions to the correct area,

"No Bed" cancellations

(iii) By service area:

transfers (how many, where, and why)

I strongly urge the use of such data to refine and update the validation of the model.

As I have indicated several times in the thesis, improved observation of the forms on patients awaiting admission would be advisable. It would allow better validation of the length of the queue and of the distribution of waiting times. In the Medical area, the careful observation of the queue might suggest some pertinent algorithm for determining whom to admit. Teaching patients will probably need to be differentiated from non-teaching patients. In the surgical area, the entire slate should be recorded first! Then additions and variations may be noted daily. Careful records will enable a more exact study of the development of the slate, particularly with respect to patient category. The collection of this data must be done in the Admitting Office and OR Booking Office. To avoid unacceptable interference with the daily operation of the OR Booking Office, it should be done "after hours". The first couple of collection sessions should be used to record information describing every day and every admission form which appears on the slate or in the file box. After that, additions, cancellations, postponements, and replacements may be noted. If done "after hours", it should also be possible to look at the copies of the slates prepared one and two days in advance. This will help particularly in noting in-hospital and other "last-minute" changes.

Due to the addition of Day Care surgery since 1974, it might be advisable to collect a more recent sample of surgery data. Furthermore, OR supervisory staff suggest that the difficulty (and hence the length) of operations has increased somewhat since 1974. For multiple OR services, data should be collected by service rather than by OR.

LOS data, as presently corrected to exclude Pediatrics, are now quite reliable. As patient volume varies however, this will require improvement.

Emergency data, particularly if supplemented by the new Admitting Office records, are adequate. Instead of the single, continuous-time sample, one taken at random dates throughout the year might be desirable.

If it is desirable to distinguish teaching beds, a comparative study of teaching and non-teaching patients' LOS would be advisable.

11.2 Model Modification and Expansion

As indicated in the comments on data, additional information may reveal a more complex mechanism for admission of Medical scheduled patients, and for development of the slate.

In particular, Section 7.3 suggests a less rigid daily bed limit for scheduled surgical patients, and modification of the appropriate algorithm so that the length of time to a requested surgery date is not completely random. In order to fill up the slates, either numbers or the whole concept of "composite" physicians may have to be modified.

Better limits and rules may also be found regarding transfers, particularly if "overflow" beds are limited.

The additional data may make it feasible to introduce extended care units to the model. Caution should be exercised however, as this complication in the model may not be warranted in terms of the additional useful information that would be obtained.

The services not yet included in the model may be implemented. However, two of these, General Surgery and Neurosurgery / Plastic Surgery are not block booked, and would require further study. This extension would be fairly expensive in terms of computer run time. Thus, it should only be done if it would be useful for experimentation, and not merely for "completeness sake".

11.3 Experiments

The questions which were mentioned in Section 2.4 and are provided in Appendix 1.4 give a number of ideas for experiments. Additional discussion with St. Paul's administration would no doubt add others, perhaps more valuable from the immediately practical point of view. Some additional suggestions follow.

The schedulable and non-schedulable admissions data may be analyzed for cyclical patterns, especially weekly. The effect of incorporating this into the model could then be tested. For example, it might be possible to generate patients each week from one distribution and to sample from that group on a daily basis.

According to administrative suggestions, there are supposed to be 18 beds reserved for the emergency patients who may arrive after the scheduled admissions. These beds could be located in the various service areas in order to test the effect of observing such a limit.

It might be of interest to check the effect of separating areas by sex. The model already provides data on average numbers of males and females in the hospital, by service. These data should provide enough of a guideline that it would be unnecessary to complicate the model by restricting beds to usage according to sex.

It is expected that the number of arrivals at the emergency unit is fairly random. The decision to admit from this unit may be regulated somewhat by occupancy. It might be possible to investigate the hypothesis of occupancy-regulated emergency admissions and incorporate findings into the model.

It would be useful to investigate and build into the model any controls on admissions or transfers which tend to maintain the occupancy levels of the various service areas at St. Paul's. An investigation of the factors which control the length of the Medical waiting line would also be instructive.

CHAPTER 12 DISCUSSION

This chapter reflects on the information gained in studying and modelling patient admissions and scheduling at St. Paul's Hospital. The first section discusses certain information revealed by the data which was surprising, when compared with formal hospital policy. The second section comments on the value of simulation in the hospital setting, from my vantage point.

12.1 System Lapses Revealed by Data

My first comment regards patient diagnostic categories as defined by an administrative directive (see Section 5.2.4). Even within a single surgical service, not all physicians interpret the categories in the same way. One physician may identify all his patients as semi-urgent, another as all elective - though the slated operational procedures are identical. The most amazing problem has to do with urgent patients who are supposed to be admitted within two weeks. A surgeon will identify his patient as urgent and request a day for surgery four or five weeks away! This is not uncommon and is not restricted to services with particularly "tight" slates. The situation is even more pronounced with Medical patients. The cross-section of waiting times in one recent sample was as in Table XVI. Notice particularly that urgent patients are supposed to be admitted within two weeks and semi-urgent patients within one month. (T = teaching)

TABLE XVI

TYPICAL CROSS-SECTION OF WAITING TIMES

Wait so far	T U	U	T SU	SU	T El	El
0-2 weeks	2	0	2	2	2	4
2 weeks-1 month	2	0	0	3	1	1
1-2 months	3	1	0	1	0	4
2-3 months	0	0	1	1	0	1
over 3 months	1	0	2	1	1	0

Perhaps the classification method should be re-examined or re-emphasized.

There is a further general problem with long-stay patients in all acute-care hospitals. This problem may be highlighted by a simple calculation in which realistic approximations have been made. Consider a service, such as Medicine, with an average length of stay of about twelve days. Seven percent of the patients stay over thirty days, for an average of fifty days. The other 93% have a mean stay of nine days. Then, 7% of the patients account for 30% of the bed-days used. This sort of information should urge improved placement of long-stay patients.

Finally, it appears that Orthopedic bed allocation by sex does not correspond to usage. It seems from my information that 40 Orthopedic beds are for males, 30 for females. The model insists that females almost always use more beds - averaging 35.5 beds to 31.4 for males.

12.2 Value of Simulation In a Hospital Context - A Personal View

My remarks on this point must be prefaced by a concern for how the project is carried out. It is true that in this case we approached St. Paul's Hospital with a proposal for a Master's thesis project. At that time, I did have a strong background in Mathematics, and some experience in computer simulation. However, if a hospital wished to carry out a study of this size, it should not consider consulting anyone without actual experience in such research. The task of becoming familiar with the hospital system, gathering and processing appropriate data, learning a computer simulation language suitable to the project, modelling the system, programming the simulation, testing and running it is, frankly, enormous. It requires a good deal of time and money.

Having said that, let me add that I believe my model is now a good one, far surpassing its expectations. Large-scale simulation can be profitable in a hospital context if performed by an individual (or preferably by a team) competent in analyzing hospital systems and in modelling and simulation. If the hospital is carefully run in terms of data collecton, of policy definition, and of adherence to that definition - so much the better. Basically a simulation model such as this one processes an input stream of patients, using certain admission and scheduling mechanisms and a certain number of beds and OR's, to produce a throughput rate, waiting line information, and "No Bed" cancellation information. Such a "black box" model, if good, and it can be, is designed to be valuable as an administrative tool.

The primary role of simulation in a hospital setting is, and for hospitals with limited resources probably should be, small-scale. Single wards or OR units can be studied relatively easily, with the studies tailored to particular questions.

The exercise of developing a large-scale model is informative in itself. An examination of the data necessary for such a model alerts the researcher to certain lapses in the system and to other aspects which invite investigation (as those in Sections 12.1 and 11.3). Having the data, he can investigate other problems which may be suggested in an unquantified form by hospital supervisory staff (such as that in Section 10.5). The implementation of such a large-scale model on a computer will reveal additional areas of the system which are particularly sensitive to the variables which affect them (such as the length of the Medical queue and the number of Medical patients placed off-service). Finally, it is possible to develop a reasonable representation of an intricate hospital system (refer to the validation in Section 9.3). The computer model can quantitatively analyze the interaction of a large number of variables, which it would be otherwise impossible to estimate effectively. From that point, there is a vast array of applications for which the model may be used (for example, refer to Chapter 10 and to Section 11.3). If in proper communication with the hospital administration, the researcher may explain the numerical results of experiments, and co-operate in analyzing the impact which would follow from the application of such experimental situations. Though not inexpensive, a computer simulation of a large-scale hospital model has valuable potential.

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APPENDICES

APPENDIX 1 (Refers to Chapter 2)

1.1 Early Specifications for the Model

MICRO-SIMULATION MODEL OF ST. PAUL'S HOSPITAL

PROJECT OBJECTIVE

To model the patient flow in and through St. Paul's Hospital.

SUB OBJECTIVES

1. To build a dynamic computerized model which can be used to provide guidelines for management action in controlling hospital admissions to effectively utilize hospital resources.
2. To determine on a daily basis how many patients to admit by specialty.
3. To demonstrate effect on hospital occupancy of adding/subtracting physicians to the medical roster. (Surgeons, non-surgeons, anaesthetists)
4. To demonstrate the effect of changing the bed allocation in the hospital.
5. To reduce the number of no-bed situations.
6. To demonstrate effect of varying numbers of emergency admissions upon bed occupancy, O.R. schedules and the number of surgical cancellations.

B.L. Curtis
July, 1975

DATA REQUIRED

For each admission/discharge for the year January 1, 1974 to December 31, 1974:

Patient's age, sex

Length of stay (or admission date and discharge date)

Primary diagnosis

Secondary diagnosis

Type of admission

Surgical procedure(s)

Attending doctor

Surgeon(s)

Hospital Service

Type of Anaesthetic

1.2 The Basic Information Flow

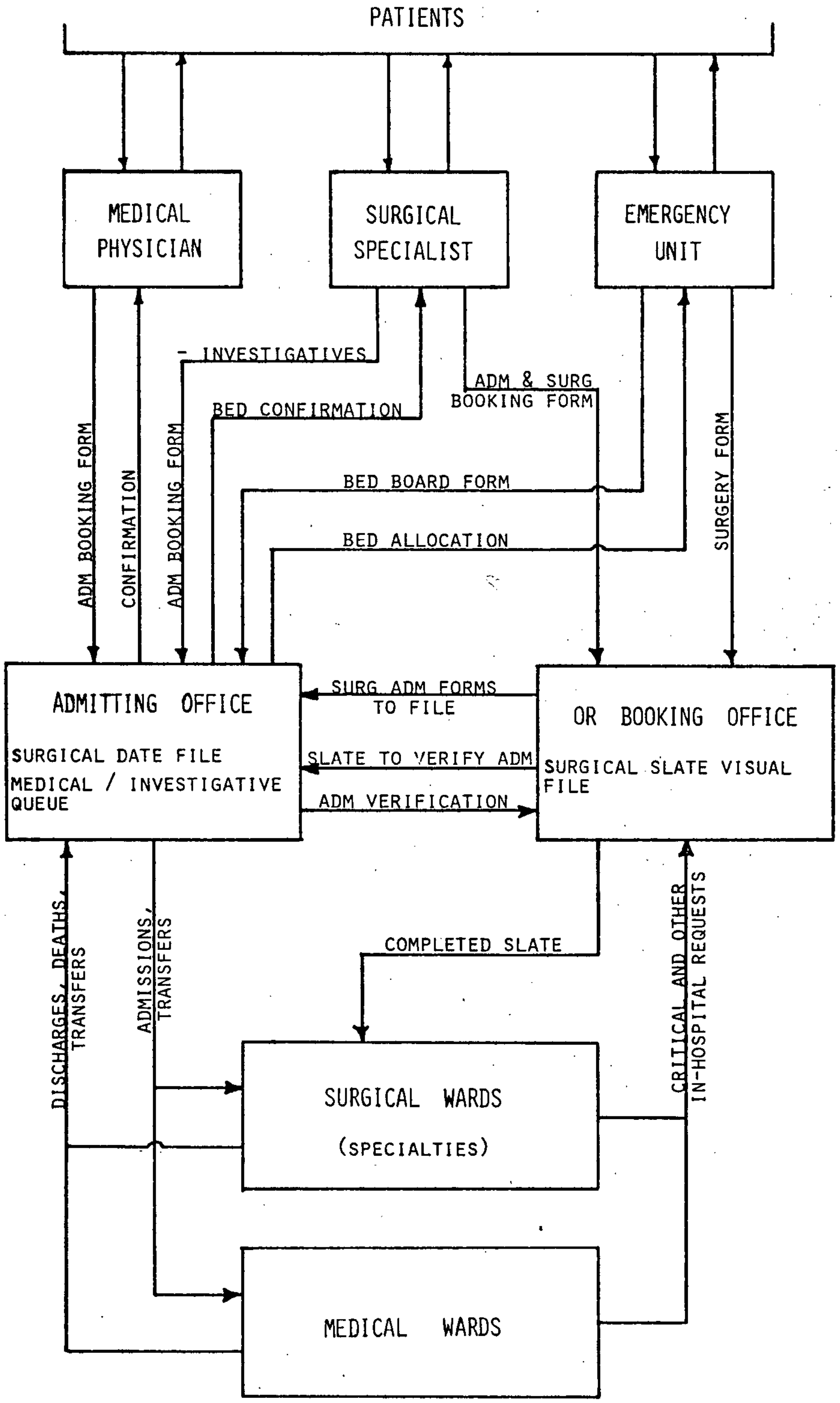

Fig. A 1.1 The basic flowchart of information

1.3 The Proposal to St. Paul's Hospital

May 17, 1976

Dr. E.C.Q. Van Tilburg,
Medical Director,
St. Paul's Hospital,
1081 Burrard Street,
Vancouver, B.C.

Dear Dr. Van Tilburg:

About a year ago Mr. Brian Curtis and myself started discussion on the problem described in the attached project description. We were restrained from actual implementation of our ideas from the lack of time and, even more importantly, the lack of a suitable collaborator who can look after the detailed work.

With Mr. Mark Chase joining our program we are now in the position to proceed with this project. Presently we are finalizing our plans which are outlined in the proposal. We are anxious to inform all concerned staff and to ensure good co-operation.

Brian Curtis has already contacted your secretary and arranged for a meeting with you on May 26th. I am looking forward to discussing the project with you in greater detail at that time.

Yours sincerely,

Chas. A. Laszlo, Ph.D.
Associate Director
Division of Health Systems

Encl.

CAL/pdw

A Proposal for the

APPLICATION OF SIMULATION TECHNIQUES TO ALLOCATION SCHEDULING, AND UTILIZATION PROBLEMS AT ST. PAUL'S HOSPITAL

A number of studies have been carried out concerned with the operation of individual departments in St. Paul's using conventional management engineering techniques. In particular, Admitting, OR Scheduling and the allocation of beds were investigated in depth. Although these studies provided important information it is now apparent that because of the complexity of the interaction of the various departments in the Hospital more sophisticated approaches are required.

The range of services provided by St. Paul's has been greatly extended and all services have been increasingly utilized mostly without corresponding increases in facilities. As a consequence of this expansion a number of operational problems have emerged:

(1) Scheduling of surgical patients;

(2) Allocation and utilization of operating rooms;

(3) Allocation and utilization of beds;

(4) Allocation and utilization of medical personnel (anesthetists, physicians, surgeons).

Some problems of scheduling and resource allocations may be investigated using modelling and simulation methods. These methods were developed in response to the demand generated by complex organizational problems in private and public institutions. Examples of successful application of modelling and simulation methods exist in manufacturing, marketing, transportation, banking and other areas.

The application of modern operational research techniques to admitting and scheduling has aroused considerable academic interest. In particular, there have been numerous reports in the literature of the possible application of the experience gained in other areas to this field. Techniques have been developed, data have been collected and computing systems and programs are available. Thus, it seems that the time is now ripe for the practical utilization of simulation techniques.

In view of the increasing acuteness of scheduling and utilization problems at St. Paul's and the possible usefulness of modelling and simulation methods, we plan to evaluate the effectiveness and potential of this approach in the St. Paul's environment. Specifically, we will:

(1) Set up a simulation model;

(2) Incorporate real and relevant data;

(3) Simulate the existing operational environment;

(4) Simulate possible alternatives for managerial evaluation.

We aim to involve all interested people in this project. Detailed reports of our progress will be made available and feedback on any and all aspects of this work are welcome.

May 1976

Brian Curtis,
Head, Management Engineering Unit,
Greater Vancouver Regional Hospitals,
Vancouver General Hospital,
Vancouver, B.C. V5Z 1M9

Mark Chase,*
Graduate Student in Applied Mathematics

Chas. A. Laszlo,*
Associate Director, Division of Health Systems,
Office of the Coordinator of Health Sciences

John H. Milsum,*
Director, Division of Health Systems,
Office of the Coordinator of Health Sciences

*4th Floor, IRC Building,
University of British Columbia,
Vancouver, B.C. V6T 1W5

1.4 "Questions" to Ask of the Model

Questions for St. Paul's Hospital Simulation

Bed Allocation

- Can the allocation of beds to services be altered to increase throughput of patients?
- What if numbers of patients in all services increases by 1%; 2%; 3% - - - 20%? Can allocation of beds be altered to cope with increase of patients? What happens to length of waiting list (in quantity and time to be admitted)
- What if additional physicians are added to one/each service? Can allocation of beds be altered to cope with increase in number of physicians? What happens to length of waiting list (in quantity and in time to be admitted)
- What if beds are not allocated by service? Can patient throughput be increased?

O.R. Scheduling

- What if O.R.'s are closed? Impact on bed occupancy; waiting list length and time to be admitted?
- What if #'s of patients increase? Impact of volume of surgeries per room, numbers of no bed occurrences.
- What if # of surgeons is increased? Impact on number of surgeries; number of no bed situations; length of waiting list and time to be admitted.
- What if beds are booked first then O.R. time? What if O.R. time is booked first then bed? Vary number of admissions; What happens to waiting list in numbers and in time to be admitted?

Emergency Admissions

- What if emergency admissions increase/decrease by percentage points; by hospital service? Impact on O.R., impact on "no bed" situation.

Seasonality

First determine - if occupancy varies with season
- if diagnoses vary with season

If the answer to above is YES
What if we vary bed allocation on seasonal basis?

InPatient Transfers

What if number of inpatient transfers increases/decreases? Impact on surgical waiting list.

B.L.C.

APPENDIX 2 (Refers to Chapter 7)

Note that the sections dealing with the derivation of data for the model are written in the form of explanations and instructions for anyone who might wish to repeat or extend the data analysis performed. Not all of the data which were analyzed appears here; the Orthopedic service has been used as an example. A complete file is available from the Division of Health Systems at the University of British Columbia.

2.1 Admitting Office Report 1976

St. Paul's Hospital

VANCOUVER 1 B.C.

REPORT FROM THE ADMITTING DEPARTMENT - JANUARY TO DECEMBER 1976

NUMBER OF ADMISSIONS	20577	(22 ADMISSIONS CANCELLED BY B.C.H.P.)
NUMBER OF DAY CARE SURGICAL ADMISSIONS	3104	(29 CANCELLED AFTER ADM - 26 ADMITTED)
NUMBER OF REGULAR AND DAY CARE ADMISSIONS	23681	
NUMBER OF NEWBORNS (INCLUDING 3 COMPANION BABES)	1491	
NUMBER OF PSYCHIATRIC ADMISSIONS	807	
NUMBER OF RENAL ADMISSIONS JANUARY - MAY	1509	
NUMBER OF RENAL OUT PATIENTS PROCESSED JUNE TO DEC.	51	
NUMBER OF EXTENDED CARE ADMISSIONS	43	
NUMBER OF EXTENDED CARE DAYS	1620	
NUMBER OF ADMISSIONS THROUGH THE EMERGENCY	7097	- 34.5% OF TOTAL ADMISSIONS
NUMBER OF URGENT DIRECT ADMISSIONS	2152	- 10.5% OF TOTAL ADMISSIONS
NUMBER OF MEDICAL ADMISSIONS	5774	- 28.06% OF TOTAL ADMISSIONS
MEDICAL ADMISSIONS TO MEDICAL AREAS	4368	- 75.7% OF TOTAL MEDICAL ADMISSIONS
MEDICAL ADMISSIONS TO OTHER AREAS	1406	- 24.4% OF TOTAL MEDICAL ADMISSIONS
EMERGENCY MEDICAL ADMISSIONS	3525	- 61.05% OF TOTAL MEDICAL ADMISSIONS
URGENT DIRECT MEDICAL ADMISSIONS	883	- 15.3% OF TOTAL MEDICAL ADMISSIONS
URGENT DIRECT SURGICAL ADMISSIONS	1089	
ADMISSIONS TO WRONG AREAS	3151	- SURGICAL 1745 - MEDICAL 1406
CANCELLATIONS FOR NO BED	372	- AN AVERAGE OF 31 PER MONTH
NUMBER OF TRANSFERS	8795	- AN AVERAGE OF 24 PER DAY
PLACEMENT OF PATIENTS IN CORRECT CLINICAL AREA	2810	
PLACEMENT OF PATIENTS IN ACCOMODATION OF CHOICE	810	
PATIENTS' CONDITION	2304	
FOR ISOLATION	272	
FOR PATIENT CARE AND MANAGEMENT	2599	
NUMBER OF PATIENTS FROM OUTSIDE GREATER VANCOUVER	5029	

Fig. A 2.1 Admitting Office report 1976

2.2 Patient Diagnostic Categories

Emergency admissions data collected on all services for 32 days showed 611 patients. This would give 6965 patients in a year. In 1976, there were actually 7097 emergency patients. Hence, the emergency data which was collected is quite reliable, although a bit low.

The total number of DU patients is known. Each service may be expected to have the same proportion of DU's as it does of emergencies.

The total admissions (excluding Obstetrics) in 1974 were 18,853 (from PAS). 1976 total admissions were 20,577. Hence, consider the PAS service totals to be quite reliable.

To get the number of schedulable patients, one can subtract emergency and DU totals from overall totals, each of these being fairly reliable. For surgical services, the slates can be used to check the number of schedulable patients, by noting that there are 250 operating days per year (slated) and reducing the total number of operations by the estimated number of in-hospital procedures. Collected arrival data may also be used to check the number of schedulable patients.

These data for Orthopedic patients appear in Table XVII.

For the scheduled patients, diagnostic category was recorded. Hence, the waiting line data may be used to determine the proportions of urgent, semi-urgent, and elective patients.

TABLE XVII

ORTHOPEDIC PATIENTS

Group	Data	Estimated per year
Total	1738 from PAS data	1740
Emergencies	57 in 32 days gives 650 in a year.	675
Direct Urgents	57 of 611 emergencies were Orthopedic, a similar proportion of 2152 DU's would be 201.	215
Schedulable	100 Orthopedic procedures in 25 days - 13 est. in-hospital (at 1 per 2 days) = 87 in 25 days or 870 in 250 days. Also, 33 waiting line admissions in 11 days would be 750 in 250 operating days.	850

Of the 51 waiting Orthopedic patients there were: 1 U; 10 SU; 40 El.

The results for diagnostic category proportions of Orthopedic patients are:

of emergency and DU patients:

.759 Emergent / .241 Direct Urgent

of schedulable patients:

.020 Urgent / .197 Semi-Urgent / .783 Elective.

2.3 Patient Arrival Distributions

The 1974 slates may be used to obtain an idea of the scheduled arrival pattern, if a weekend effect is added. For example, if pre-operative LOS is constant, there will be no scheduled admissions on 2/7 of the days.

The observed arrival pattern of emergency patients may be incremented and smoothed by DU arrivals - arbitrarily. In Medicine, where there is a significant number of DU admissions, a possible arrival distribution for them was hypothesized and combined multiplicatively with that of emergency patients to give the non-schedulable patients' arrival distribution.

The individual rates may need to be modified to match totals of the preceding section.

The data which determined the proportion of times for a given number of arrivals per day, in the schedulable and immediate classifications, appear in Table XVIII.

TABLE XVIII

ORTHOPEDIC ARRIVALS

arrivals per day	schedulable number	proportion of times	emergency number	with D.U.	proportion of times
0	10	.2857	6	6	.1622
1	1	.0286	9	6	.1622
2	4	.1143	6	9	.2432
3	8	.2285	7	7	.1892
4	6	.1714	1	6	.1622
5	6	.1714	2	2	.0541
6				1	.0270

If the random number generator yields a uniform distribution, a calculation reveals that these proportions should yield 1745.7 Orthopedic patients per year, which is close enough to the approximately 1740 desirable.

2.4 Patient Sex and Age Groups

First of all, it is useful to tabulate the number of patients in each age group / sex category for the PAS data, and count and tabulate similarly for all collected Slate and Emergency data (of 1976). Calculate the percentages of each sex and of each age group within sex for these samples. The PAS data should be modified slightly in the direction of the smaller sample data, to give a final set of percentages to use. In the age data, since PAS includes Pediatric patients which are no longer a St. Paul's service group, a further stage is useful. In the PAS data, arbitrarily fix the percentage of patients in the 0-14 age group at a level compatible with the 1976 data. Compute the other percentages again so that they fill the remaining total in the same proportions as before. Use this set of values to combine with the 1976 values for a final figure. These data for Orthopedic patients follow in Tables XIX - XXI.

TABLE XIX

SEX OF ORTHOPEDICS

PAS	54.37% male
1976	51.26% male
USE	53.5 % male

TABLE XX

ORTHOPEDIC MALE AGE GROUPS

Age group	PAS %	PAS with 1st gp set	1976	USE
0-14	7.20	2.00	1.64	2
15-34	39.37	41.57	44.26	43
35-54	31.01	32.75	34.43	33
55-74	18.20	19.22	16.39	18
75 +	4.23	4.45	3.28	4

TABLE XXI

ORTHOPEDIC FEMALE AGE GROUPS

Age group	PAS %	PAS with 1st gp set	1976	USE
0-14	5.93	2.00	0.00	2
15-34	24.09	25.10	39.66	30
35-54	21.82	22.74	29.31	20.5
55-74	27.99	29.17	29.31	29
75 +	20.18	21.03	15.22	18.5

2.5 Patient Length of Stay

The age group / sex tabulation for LOS, produced from the PAS data appears on the next page (Table XXII).

Clearly the average LOS for females (16.36) is much higher than that for males (12.38). Instead of being based on sex, this difference can be explained by age - since there are more females in the older (longer stay) groups. To test this, the proportion of <u>males</u> in each age group was multiplied by the average LOS of <u>females</u> in each age group. This was thought to give a value which could be compared to the male overall average with the effect of age removed.

7.02 (68 / 945) + 9.04 (372 / 945) + 11.13 (293 / 945) + 17.61 (172 / 945) + 31.79 (40 / 945) =

12.06 ... modified female average vs

12.38 ... male average

As a result, it was decided that since the model already assigned age group by sex, it would suffice to assign LOS based on age group only (i.e. regardless of sex, the LOS would be sampled from the distribution corresponding to the age group of the patient).

To see how the LOS distribution was obtained for a particular age group, consider the 35-54 age group of Orthopedics in Table XXIII.

TABLE XXII

PAS LOS TABULATION

LENGTH OF STAY	
Patients staying:	0 days
	1 day
	2-3 days
	4-7 days
	8-15 days
	16-31 days
	32-63 days
	64+ days
	Total patients
	Total days
	Sum of squares of days
Average Days	

AGE GROUP/SEX		MALE	FEMALE	ALL
0-14	0 days	0	0	0
	1 day	11	3	14
	2-3 days	18	16	34
	4-7 days	18	12	30
	8-15 days	8	11	19
	16-31 days	11	5	16
	32-63 days	2	0	2
	64+ days	0	0	0
	Total patients	68	47	115
	Total days	560	330	890
	Sum of squares of days	10656	4226	14882
	Average Days	8.24	7.02	7.74
15-34	0 days	3	1	4
	1 day	12	5	17
	2-3 days	81	38	119
	4-7 days	177	89	266
	8-15 days	67	37	104
	16-31 days	19	10	29
	32-63 days	9	9	18
	64+ days	4	2	6
	Total patients	372	191	563
	Total days	3211	1726	4937
	Sum of squares of days	124109	43364	167473
	Average Days	8.63	9.04	8.77
35-54	0 days	2	2	4
	1 day	5	4	9
	2-3 days	48	26	74
	4-7 days	107	54	161
	8-15 days	71	46	117
	16-31 days	41	34	75
	32-63 days	15	6	21
	64+ days	4	1	5
	Total patients	293	173	466
	Total days	3372	1926	5298
	Sum of squares of days	98696	45386	144082
	Average Days	11.51	11.13	11.37
55-74	0 days	2	1	3
	1 day	2	6	8
	2-3 days	27	30	57
	4-7 days	34	58	92
	8-15 days	43	37	80
	16-31 days	40	56	96
	32-63 days	18	28	46
	64+ days	6	6	12
	Total patients	172	222	394
	Total days	2857	3909	6766
	Sum of squares of days	102115	172467	274582
	Average Days	16.61	17.61	17.17
GE 75	0 days	0	0	0
	1 day	1	0	1
	2-3 days	1	5	6
	4-7 days	6	13	19
	8-15 days	4	27	31
	16-31 days	9	60	69
	32-63 days	9	40	49
	64+ days	10	15	25
	Total patients	40	160	200
	Total days	1701	5086	6787
	Sum of squares of days	141359	277956	419315
	Average Days	42.52	31.79	33.93
ALL	0 days	7	4	11
	1 day	31	18	49
	2-3 days	175	115	290
	4-7 days	342	226	568
	8-15 days	193	158	351
	16-31 days	120	165	285
	32-63 days	53	83	136
	64+ days	24	24	48
	Total patients	945	793	1738
	Total days	11701	12977	24678
	Sum of squares of days	476935	543399	1020334
	Average Days	12.38	16.36	14.20

TABLE XXIII

EMPIRICAL LOS : AGE 35-54 ORTHOPEDICS

Days	No. of patients	Percentage	Cumulative Percentage	Time less than ...
0-1	13	2.79	2.79	2
2-3	74	15.88	18.67	4
4-7	161	34.55	53.22	8
8-15	117	25.11	78.33	16
16-31	75	16.09	94.42	32
32-63	21	4.51	98.93	64
64 +	5	1.07	100.00	... (arbitrarily ended about 128)

These points, which had been selected in an effort to have logarithmic intervals in order to test a lognormal fit to the curves, were plotted on logarithmic probability paper. (See Figure A 2.2 which follows.)

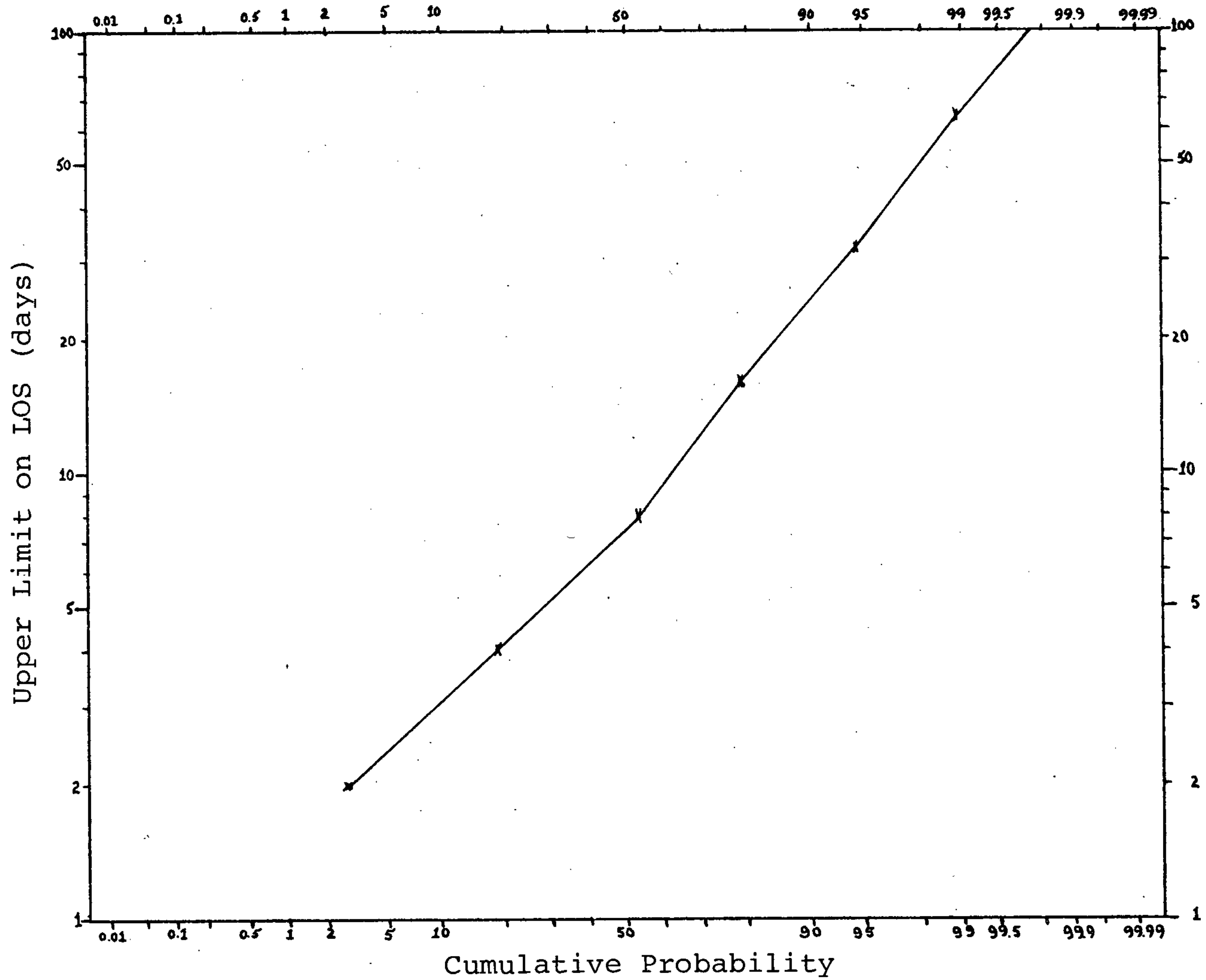

Fig. A 2.2 Logarithmic probability plot of LOS for age 35-54 Orthopedics

These original points were connected by straight line segments (or approximated by a smooth curve). Additional points were then taken from the curve. The points finally used for age 35-54 Orthopedics appear in Table XXIV.

TABLE XXIV

PROCESSED LOS : AGE 35-54 ORTHOPEDICS

Up to n days	Cumulative percentage
1	0.0
2	2.8
4	18.7
6	37.0
8	53.2
10	62.0
12	68.7
16	78.3
20	85.2
24	88.9
32	94.4
40	96.6
48	97.7
64	98.9
80	99.5
96	99.7
128	100.0

Note: No patients were considered to have 0 days stay, as there is a separate Day Care surgery service now, and such patients would not count on the census.

The large number of intermediate points taken from the graph were of value because the GPSS function generator interpolates linearly between adjacent points. The "linear" or smooth interpolation done on the graph paper is better, being done against a logarithmic scale for which the curve is straighter.

2.6 Length of Surgery

From the 1974 slates, length-of-surgery data were obtained. Tables were made in which the various lengths were recorded for each age group / sex classification. From this, a table of number of patients and average time (in minutes) could be made (see Table XXV).

TABLE XXV

ORTHOPEDIC LENGTH OF SURGERY

Age		M	F	ALL
0-14	patients	4	5	9
	avg. time	41	49	46
15-34	patients	21	10	31
	avg. time	70	60	67
35-54	patients	27	18	45
	avg. time	71	67	69
55-74	patients	13	18	31
	avg. time	79	75	76
75 +	patients	1	13	14
	avg. time	60	111	108
ALL	patients	66	64	130
	avg. time	70.3	75.5	72.9

As noted previously, it was decided that age would be considered relevant, but not sex.

For each sex group, empirical data were recorded and smoothed to give the function used (see Table XXVI).

TABLE XXVI

LENGTH OF SURGERY : AGE 15-54 ORTHOPEDICS

Empirical		Processed			
Minutes	Patients	Minutes	Patients	%	Cum. %
15	2	30	3	9.74	9.7
25	1	45	2	6.45	16.1
45	2	50	4	12.9	29.0
50	4	55	4	12.9	41.9
55	4	60	3	9.74	51.6
60	2	65	3	9.74	61.3
65	3	70	2	6.45	67.7
70	2	75	2	6.45	74.2
75	3	80	1	3.23	77.4
80	1	90	2	6.45	83.9
85	1	100	2	6.45	90.3
90	1	110	1	3.23	93.5
95	1	120	1	3.23	96.8
100	1	130	1	3.23	100.0
110	1				
120	1				
140	1				

APPENDIX 3 PROGRAM LISTING

```
      REALLOCATE BLO,1000,FAC,10,STO,10,QUE,200,TAB,50,VAR,100,FSV,10
      REALLOCATE COM,146440
      SIMULATE
      RMULT      5177,169,27279,6343
***************************************
*   TABLE OF DEFINITIONS
***************************************
*
* ADIST VARIABLE                    *IDENTIFIES SERVICE/SEX AGE DIST FUNCTION
* ADMMC CHAIN                       *MEDICAL ADMISSIONS
* ADMSC CHAIN                       *SURGERY ADMISSIONS
* ALTER MATRIX                      *ALTERNATE AREAS FOR EMERGENCIES
* ANEEN FUNCTION                    *NON-SCHEDULABLE EENT ARRIVALS
* ANMED FUNCTION                    *NON-SCHEDULABLE MEDICAL ARRIVALS
* ANORP FUNCTION                    *NON-SCHEDULABLE ORTHOPEDIC ARRIVALS
* APRWK VARIABLE                    *IDENTIFY APPR WEEK ON MATRIX
* ARNON FUNCTION                    *NON-SCHEDULABLE ARRIVALS BY SERVICE
* ARSCH FUNCTION                    *SCHEDULABLE ARRIVALS BY SERVICE
* ASEEN FUNCTION                    *SCHEDULABLE EENT ARRIVALS
* ASMED FUNCTION                    *SCHEDULABLE MEDICAL ARRIVALS
* ASORP FUNCTION                    *SCHEDULABLE ORTHOPEDIC ARRIVALS
* BTIME BVARIABLE                   *ENUF TIME IF THIS ONE SUBSTITUTED?
* BUMPE BVARIABLE                   *TO BUMP ELECTIVE OF THIS DOCTOR
* BUMPS BVARIABLE                   *TO BUMP SEMIURGENT OF THIS DOCTOR
* CANCL SAVEVALUE                   *COUNTS NUMBER OF CANCELLATIONS
* CHECK SAVEVALUE                   *DAY TO CHECK ON SLATES
* CHKDR SAVEVALUE                   *DOCTOR TO CHECK
* CHKTM SAVEVALUE                   *SURGERY TIME TO CHECK FOR
* CTPRI VARIABLE                    *PRIORITIES U:19 SU:18 EL:17
* CWEEK VARIABLE                    *NUMBER OF WEEKS TO CHECK DATE
* DASAM VARIABLE                    *NEW OR REALLY ON SAME DAY?
* DISCH CHAIN                       *DISCHARGE CHAIN
* DSTRQ VARIABLE                    *SERVICE/CATEGORY FUNCTION OF DAYS TO REQ
* EENNO MATRIX                      *FOR EENT NUMBERS
* EENSL MATRIX                      *FOR EENT SLATE
* EENSN TABLE                       *EENT SLATE NUMBERS
* EENST TABLE                       *EENT SLATE TIME
* EINO  QUEUE                       *EENTS IN EMERG
* EIN2  QUEUE                       *EENTS IN GSG ETC.
* EIN4  QUEUE                       *EENTS IN ORTHO
* EMARR SAVEVALUE                   *COUNTS EMERG AND D.U. ARRIVALS TODAY
```

```
* EMBED SAVEVALUE        *TRACKS EMERGENCY BEDS IN USE
* EMGDU TABLE            *EMERG AND D.U. ARRIVALS DAILY
* EMGNO SAVEVALUE        *EMERGENCY NUMBER OPERATED
* EMGTM SAVEVALUE        *EMERGENCY OPERATING TIME
* EMRGC CHAIN            *EMERGENCY OPERATIONS CHAIN
* EMTBN TABLE            *EMERGENCY OPERATED NUMBER
* EMTBT TABLE            *EMERGENCY OPERATED NUMBER
* ENDWK VARIABLE         *IS DATE ON WEEKEND?
* EOPNO SAVEVALUE        *EENT NUMBER OPERATED
* EOPTM SAVEVALUE        *EENT OPERATING TIME
* GOPTM SAVEVALUE        *GENERAL SURGERY OPERATING TIME
* GSGNO MATRIX           *FOR GENERAL SURGERY NUMBERS
* GSGSN TABLE            *GENERAL SURGERY SLATE NUMBERS
* GSGST TABLE            *GENERAL SURGERY SLATE TIME
* HITBL VARIABLE         *NUMBER OF THE HIGHEST OPERATIONS TABLE
* HLONG VARIABLE         *NUMBER OF WEEKS WAITED FOR OPERATION
* LDIST VARIABLE         *IDENTIFIES SERVICE/AGE LOS DIST FUNCTION
* LOSEE QUEUE            *EENT L OF STAY
* LOSEF QUEUE            *EENT FEMALES L OF STAY
* LOSEM QUEUE            *EENT MALES L OF STAY
* LOSME QUEUE            *MEDICINE L OF STAY
* LOSMF QUEUE            *MEDICINE FEMALES L OF STAY
* LOSMM QUEUE            *MEDICINE MALES L OF STAY
* LOSOF QUEUE            *ORTHOPEDICS FEMALES L OF STAY
* LOSOM QUEUE            *ORTHOPEDICS MALES L OF STAY
* LOSOR QUEUE            *ORTHOPEDICS L OF STAY
* LOSQ  VARIABLE         *IDENTIFIES SERVICE'S LOS QUEUE
* LOSQS VARIABLE         *IDENTIFIES SERVICE/SEX LOS QUEUE
* MACHD BVARIABLE        *TO MATCH PATIENT ON DISCHARGE CHAIN
* MACHR BVARIABLE        *TO MATCH PATIENT ON ADM OR SURG CHAIN
* MACHS BVARIABLE        *USED IN THE ABOVE
* MADIS SAVEVALUE        *MEDICAL AREA DISCHARGES
* MALT3 CHAIN            *MEDICAL PATIENTS IN AREA 3
* MALT4 CHAIN            *MEDICAL PATIENTS IN AREA 4
* MDATE SAVEVALUE        *ADMISSION (OR ANOTHER) DATE TO MATCH
* MDGEN SAVEVALUE        *DATE GENERATED TO MATCH
* MEDNO MATRIX           *FOR MEDICINE NUMBERS
* MEMRN SAVEVALUE        *MEDICAL EMGDU IN MORNING
* MINO  QUEUE            *MEDICALS IN EMERG
* MIN2  QUEUE            *MEDICALS IN GSG ETC.
* MIN3  QUEUE            *MEDICALS IN EENT
* MIN4  QUEUE            *MEDICALS IN ORTHO
* MLOSG SAVEVALUE        *LENGTH OF SURGERY TO MATCH
* MLOST SAVEVALUE        *LENGTH OF STAY TO MATCH
* MOD6  VARIABLE         *IDENTIFY NEW WEEK 0 SLATES
* MOFF  VARIABLE         *IDENTIFIES MED-OFF-SERVICE CHAIN
* MSPAC VARIABLE         *NUMBER OF BEDS FOR MED SCHEDS
* MSRVC SAVEVALUE        *SERVICE TO MATCH
* NOBD  SAVEVALUE        *COUNTS NUMBER OF 'NO BEDS'
* NOBED TABLE            *TABULATES NUMBER OF 'NO BEDS'
* NOFF  VARIABLE         *NUMBER TO PUT BACK ON SERVICE
* NOWTM SAVEVALUE        *TIME USED BEFORE A BUMP
* OFFSL VARIABLE         *OFFSET TO SLATE MATRIX BY SERVICE
* OINO  QUEUE            *ORTHOS IN EMERG
* OIN2  QUEUE            *ORTHOS IN GSG ETC.
* OIN3  QUEUE            *ORTHOS IN EENT
* OOPNO SAVEVALUE        *ORTHOPEDICS NUMBER OPERATED
* OOPTM SAVEVALUE        *ORTHOPEDICS OPERATING TIME
* ORPNO MATRIX           *FOR ORTHOPEDIC NUMBERS
* ORPSL MATRIX           *FOR ORTHOPEDIC SLATE
```

```
* ORPSN TABLE                                *ORTHOPEDIC SLATE NUMBERS
* ORPST TABLE                                *ORTHOPEDIC SLATE TIME
* PTFWK SAVEVALUE                            *ROW OF PTS FOR THE APPROPRIATE WEEK
* PWEEK SAVEVALUE                            *FIRST DAY OF PRESENT WEEK (SUNDAY)
* SDIST VARIABLE                             *IDENTIFIES SERVICE/AGE L OF SURGERY
* SEUSC VARIABLE                             *FOR 'SLATE END' CHAIN, BY SERVICE
* SGYDW VARIABLE                             *SERVICE FUNCTION FOR SURGERY DOW
* SHIFT VARIABLE                             *IDENTIFIES DAY OR NIGHT-SHIFT FUNCTION
* SIXWK BVARIABLE                            *THESE OPNS IN NEW 6TH WEEK
* SLEEN CHAIN                                *EENT END SLATE
* SLEW1 CHAIN                                *EENT WEEK 1 SLATE
* SLEW2 CHAIN                                *EENT WEEK 2 SLATE
* SLEW3 CHAIN                                *EENT WEEK 3 SLATE
* SLEW4 CHAIN                                *EENT WEEK 4 SLATE
* SLEW5 CHAIN                                *EENT WEEK 5 SLATE
* SLEW6 CHAIN                                *EENT WEEK 6 SLATE
* SLOEN CHAIN                                *ORTHO END SLATE
* SLOW1 CHAIN                                *ORTHO WEEK 1 SLATE
* SLOW2 CHAIN                                *ORTHO WEEK 2 SLATE
* SLOW3 CHAIN                                *ORTHO WEEK 3 SLATE
* SLOW4 CHAIN                                *ORTHO WEEK 4 SLATE
* SLOW5 CHAIN                                *ORTHO WEEK 5 SLATE
* SLOW6 CHAIN                                *ORTHO WEEK 6 SLATE
* SLUSC VARIABLE                             *SLATE CHAIN TO USE BY WEEK
* SRVOP VARIABLE                             *SAVEVALUES OF OPN STATS BY SERVICE
* STA1  QTABLE                               *MEDICINE LENGTH OF STAY
* STA3  QTABLE                               *EENT LENGTH OF STAY
* STA4  QTABLE                               *ORTHOPEDIC LENGTH OF STAY
* TMFWK SAVEVALUE                            *ROW OF TIME FOR THE APPROPRIATE WEEK
* TRYDA BVARIABLE                            *PTS AND TIME OK THIS DAY?
* TRYDR VARIABLE                             *DESIRED DAY AND DOCTOR'S DAY CORRESPOND?
* USRSL SAVEVALUE                            *POINTER FOR SLATES AND CHAINS
* VTIME VARIABLE                             *TIME AFTER SUBSTITUTING
* WAIT  LOGIC SWITCH                         *GATE ON SURGICAL ARRIVALS
* WAITE LOGIC SWITCH                         *GATE ON EMERGENCY ARRIVALS
* WAITQ VARIABLE                             *IDENTIFIES SERVICE/CATEGORY WAIT QUEUE
* WEEK  SAVEVALUE                            *WEEK TO CHECK FOR OPEN SPOTS ON SLATE
* WEENE QUEUE                                *EENT ELECTIVE WAITS
* WEENS QUEUE                                *EENT SEMI-URGENT WAITS
* WEENU QUEUE                                *EENT URGENT WAITS
* WKDAY VARIABLE                             *DAY-OF-THE-WEEK (TOMORROW)
* WKEND BVARIABLE                            *WEEKEND?
* WMEDE QUEUE                                *MEDICAL ELECTIVE WAITS
* WMEDS QUEUE                                *MEDICAL SEMI-URGENT WAITS
* WMEDU QUEUE                                *MEDICAL URGENT WAITS
* WORPE QUEUE                                *ORTHOPEDICS ELECTIVE WAITS
* WORPS QUEUE                                *ORTHOPEDICS SEMI-URGENT WAITS
* WORPU QUEUE                                *ORTHOPEDICS URGENT WAITS
* WRONG VARIABLE                             *INDICATES WRONG AREA QUEUE
* WTE1  QTABLE                               *MEDICAL ELECTIVE WAITS
* WTE3  QTABLE                               *EENT ELECTIVE WAITS
* WTE4  QTABLE                               *ORTHOPEDICS ELECTIVE WAITS
* WTS1  QTABLE                               *MEDICAL SEMI-URGENT WAITS
* WTS3  QTABLE                               *EENT SEMI-URGENT WAITS
* WTS4  QTABLE                               *ORTHOPEDICS SEMI-URGENT WAITS
* WTU1  QTABLE                               *MEDICAL URGENT WAITS
* WTU3  QTABLE                               *EENT URGENT WAITS
* WTU4  QTABLE                               *ORTHOPEDICS URGENT WAITS
* XFERC CHAIN                                *TRANSFERS' CHAIN
*********************************************
```

```
*   MATRIX SAVEVALUES
****************************************
*
*   MATRIX SAVEVALUE FOR EACH SERVICE. ROW 1-5 CORRESPONDS TO DIAGNOSTIC
*   CATEGORY. ROW 6 IS THE TOTAL OF ROWS 1-5. THE COLUMNS ARE:
*       1           NO. GENERATED
*       2           NO. ADMITTED
*       3           NO. OF THOSE ADMITTED REQUESTING PARTICULAR DATE
*       4           NO. WHO GOT THAT DATE
*       5           NO. ADMITTED TO WRONG AREA
*       6           NO. OF THOSE RETURNED TO CORRECT AREA
*
 MEDNO EQU        1,Y
 MEDNO MATRIX     H,6,6                   *FOR MEDICINE NUMBERS
 GSGNO EQU        2,Y
 GSGNO MATRIX     H,6,6                   *FOR GENERAL SURGERY NUMBERS (NOT USED)
 EENNO EQU        3,Y
 EENNO MATRIX     H,6,6                   *FOR EENT NUMBERS
 ORPNO EQU        4,Y
 ORPNO MATRIX     H,6,6                   *FOR ORTHOPEDIC NUMBERS
*
*   MATRIX SAVEVALUE FOR EACH BLOCK BOOKED SERVICE (2-6). COLUMNS CORRESPOND
*   TO MONDAY THROUGH FRIDAY. THE ROWS ARE:
*       1           NEXT DAY - INITIALIZE
*       2           OUTPATIENTS FOR WEEK 1
*       3           TIME FOR WEEK 1
*       4           OUTPATIENTS FOR WEEK 2
*       ...
*       13          TIME FOR WEEK 6
*   NOTE: WEEKS ARE ON A CYCLE. INITIALLY 0TH WEEK IS WEEK 1, THEN 2...
*
 EENSL EQU        9,Y
 EENSL MATRIX     H,13,5                  *FOR EENT SLATE
 ORPSL EQU        10,Y
 ORPSL MATRIX     H,13,5                  *FOR ORTHOPEDIC SLATE
       INITIAL    MH9-MH10(1,1),2/MH9-MH10(1,2),3/MH9-MH10(1,3),4
       INITIAL    MH9-MH10(1,4),5/MH9-MH10(1,5),6
*
*   ALLOW AT MOST THREE ALTERNATE BED AREAS FOR EMERGENCY PATIENTS.
*   THE ROW CORRESPONDS TO THE PATIENT'S SERVICE. THE NUMBER
*   INSERTED CORRESPONDS TO THE ALTERNATE AREA. COLUMNS ARE USED IN
*   REVERSE ORDER. 0 INDICATES NO OPTION. (EG. ROW 4...ORTHO, MAY
*   TRY SERVICE 3'S BEDS...EENT, OR THE SERVICE 2 BEDS...ORTHO).
*
 ALTER EQU        14,Y
 ALTER MATRIX     H,7,3                   *ROWS AS SERVICES
       INITIAL    MH14(1,1),2/MH14(1,2),4/MH14(1,3),3
       INITIAL    MH14(3,2),2/MH14(3,3),4/MH14(4,2),2/MH14(4,3),3
****************************************
*   HALFWORD SAVEVALUES
****************************************
*
 CANCL EQU        13,H                    *COUNTS NUMBER OF CANCELLATIONS
*   DAY TO CHECK FOR OPEN SPOTS ON SLATE
 CHECK EQU        1,H
 CHKDR EQU        5,H                     *DOCTOR TO CHECK
 CHKTM EQU        6,H                     *SURGERY TIME TO CHECK FOR
 EMARR EQU        14,H                    *COUNTS EMERG AND O.U. ARRIVALS TODAY
 EMBED EQU        11,H                    *TRACKS EMERGENCY BEDS IN USE
 EMGNO EQU        33,H                    *EMERGENCY NUMBER OPERATED
```

```
EMGTM EQU        32,H                      *EMERGENCY OPERATING TIME
EOPNO EQU        23,H                      *EENT NUMBER OPERATED
EOPTM EQU        22,H                      *EENT OPERATING TIME
GOPTM EQU        20,H                      *GENERAL SURGERY OPERATING TIME
MADIS EQU        40,H                      *MEDICAL AREA DISCHARGES
MDATE EQU        7,H                       *ADMISSION (OR ANOTHER) DATE TO MATCH
MDGEN EQU        38,H                      *DATE GENERATED TO MATCH
MEMRN EQU        41,H                      *MEDICAL EMGDU IN MORNING
MLOSG EQU        9,H                       *LENGTH OF SURGERY TO MATCH
MLOST EQU        8,H                       *LENGTH OF STAY TO MATCH
MSRVC EQU        34,H                      *SERVICE TO MATCH
NOBD  EQU        12,H                      *COUNTS NUMBER OF 'NO BEDS'
NOWTM EQU        37,H                      *TIME USED BEFORE A BUMP
OOPNO EQU        25,H                      *ORTHOPEDICS NUMBER OPERATED
OOPTM EQU        24,H                      *ORTHOPEDICS OPERATING TIME
PTFWK EQU        35,H                      *ROW OF PTS FOR THE APPROPRIATE WEEK
PWEEK EQU        3,H                       *FIRST DAY OF PRESENT WEEK (SUNDAY)
SHIFT EQU        39,H                      *IDENTIFIES DAY OR NIGHT-SHIFT FUNCTION
TMFWK EQU        36,H                      *ROW OF TIME FOR THE APPROPRIATE WEEK
*    WHICH OF THE 6 WEEKS IS THE NEXT (POINTER FOR SLATES AND CHAINS)
USRSL EQU        4,H
*    WEEK TO CHECK FOR OPEN SPOTS ON SLATE
WEEK  EQU        2,H                       *TAKES VALUES FROM 0
      INITIAL    XH$PWEEK,1/XH$USRSL,1
****************************************
*    BOOLEAN VARIABLES
****************************************
*
BTIME BVARIABLE  V$VTIME'LE'FN241      *ENUF TIME IF THIS ONE SUBSTITUTED?
BUMPE BVARIABLE  P5'E'XH$CHKDR*P6'E'5*BV$BTIME *TO BUMP ELECTIVE OF THIS DR
BUMPS BVARIABLE  P5'E'XH$CHKDR*P6'E'4*BV$BTIME *TO BUMP SEMIURGENT, THIS DR
*    TO MATCH PATIENT ON DISCHARGE CHAIN
MACHD BVARIABLE  BV$MACHS*P2'E'XH$MDGEN*P3'E'XH$MDATE*P9'E'XH$MLOST
*    TO MATCH TRANSACTION ON ADMISSION CHAIN OR SURGERY CHAIN
MACHR BVARIABLE  BV$MACHD*P11'E'XH$MLOSG
MACHS BVARIABLE  P1'E'XH$MSRVC         *USED IN THE ABOVE
SIXWK BVARIABLE  (P4'LE'XH$MDATE)      *THESE OPNS IN NEW 6TH WEEK
TRYDA BVARIABLE  P13'LE'FN240*P14'LE'FN241 *PTS AND TIME OK THIS DAY?
WKEND BVARIABLE  V$WKDAY'E'6+V$WKDAY'E'0 *TODAY FRIDAY OR SATURDAY?
****************************************
*    VARIABLES
****************************************
*
ADIST VARIABLE   38+P1*2+P7            *IDENTIFIES SERVICE/SEX AGE DIST FUNCTION
APRWK VARIABLE   ((XH$USRSL+XH$WEEK-1)@6+1)*2 *IDENTIFY APPR WEEK ON MATRIX
CTPRI VARIABLE   22-P6                 *PRIORITIES U:19 SU:18 EL:17
CWEEK VARIABLE   (XH$CHECK-XH$PWEEK)/7 *NUMBER OF WEEKS TO CHECK DATE
DASAM VARIABLE   (XH$CHECK-P14)@7      *NEW DR REALLY ON SAME DAY?
DSTRQ VARIABLE   145+P1*5+P6           *SERVICE/CATEGORY FUNCTION OF DAYS TO REQ
ENDWK VARIABLE   P13-XH$PWEEK-5        *IS DATE IN P13 ON WEEKEND?
HITBL VARIABLE   P1*2-2                *NUMBER OF THE HIGHEST OPERATIONS TABLE
HLONG VARIABLE   (P13-P2)/7            *NUMBER OF WEEKS WAITED FOR OPERATION
LDIST VARIABLE   45+P1*5+P8            *IDENTIFIES SERVICE/AGE LOS DIST FUNCTION
LOSQ  VARIABLE   37+P1*3               *IDENTIFIES SERVICE'S LOS QUEUE
LOSQS VARIABLE   37+P1*3+P7            *IDENTIFIES SERVICE/SEX LOS QUEUE
MOD6  VARIABLE   XH$USRSL@6+1          *IDENTIFY NEW WEEK 0 SLATES
MOFF  VARIABLE   47+P14                *IDENTIFIES MED-OFF-SERVICE CHAIN
MSPAC VARIABLE   R1-3                  *NUMBER OF BEDS FOR MED SCHEDS
NOFF  VARIABLE   P2-R*1                *NUMBER TO PUT BACK ON SERVICE
OFFSL VARIABLE   P1+6                  *OFFSET TO SLATE MATRIX BY SERVICE
```

```
SDIST VARIABLE    245+P1*5+P8           *IDENTIFIES SERVICE/AGE L OF SURGERY
SEUSC VARIABLE    (P1-2)*7+7            *FOR 'SLATE END' CHAIN, BY SERVICE
SGYDW VARIABLE    198+P1                *SERVICE FUNCTION FOR SURGERY DOW
SLUSC VARIABLE    (P1-2)*7+(XH$WEEK+XH$USRSL-1)@6+1 *SLATE CHAIN TO USE BY WEEK
SRVOP VARIABLE    16+P1*2               *SAVEVALUES OF OPN STATS BY SERVICE
TRYDR VARIABLE    (P13-P14)@7           *DESIRED DAY AND DOCTOR'S DAY CORRESPOND?
VTIME VARIABLE    XH$NOWTM-P11+XH$CHKTM   *TIME AFTER SUBSTITUTING
WAITQ VARIABLE    (P1-1)*5+P6           *IDENTIFIES SERVICE/CATEGORY WAIT QUEUE
WKDAY VARIABLE    P3-XH$PWEEK+1         *DAY-OF-THE-WEEK (TOMORROW)
WRONQ VARIABLE    53+(P1*8)+P14         *INDICATES WRONG AREA QUEUE
***************************************
*    QUEUES AND QTABLES
***************************************
*
*    FOR WAITS
WMEDU EQU         3,Q                   *MEDICAL URGENT
WMEDS EQU         4,Q                   *MEDICAL SEMI-URGENT
WMEDE EQU         5,Q                   *MEDICAL ELECTIVE
WTU1  QTABLE      WMEDU,0,2,23
WTS1  QTABLE      WMEDS,0,2,23
WTE1  QTABLE      WMEDE,0,2,23
WEENU EQU         13,Q                  *EENT URGENT
WEENS EQU         14,Q                  *EENT SEMI-URGENT
WEENE EQU         15,Q                  *EENT ELECTIVE
WTU3  QTABLE      WEENU,0,2,24
WTS3  QTABLE      WEENS,0,2,30
WTE3  QTABLE      WEENE,0,2,37
WORPU EQU         18,Q                  *ORTHOPEDICS URGENT
WORPS EQU         19,Q                  *ORTHOPEDICS SEMI-URGENT
WORPE EQU         20,Q                  *ORTHOPEDICS ELECTIVE
WTU4  QTABLE      WORPU,0,2,19
WTS4  QTABLE      WORPS,0,2,23
WTE4  QTABLE      WORPE,0,2,27
*    LENGTH OF STAY
LOSME EQU         40,Q                  *MEDICINE
LOSMM EQU         41,Q                  *MEDICINE MALES
LOSMF EQU         42,Q                  *MEDICINE FEMALES
STA1  QTABLE      LOSME,0,3,32
LOSEE EQU         46,Q                  *EENT
LOSEM EQU         47,Q                  *EENT MALES
LOSEF EQU         48,Q                  *EENT FEMALES
STA3  QTABLE      LOSEE,0,3,17
LOSOR EQU         49,Q                  *ORTHOPEDICS
LOSOM EQU         50,Q                  *ORTHOPEDICS MALES
LOSOF EQU         51,Q                  *ORTHOPEDICS FEMALES
STA4  QTABLE      LOSOR,0,3,32
*    WRONG AREA
MIN0  EQU         61,Q                  *MEDICALS IN EMERG
MIN2  EQU         63,Q                  *MEDICALS IN GSG ETC.
MIN3  EQU         64,Q                  *MEDICALS IN EENT
MIN4  EQU         65,Q                  *MEDICALS IN ORTHO
EIN0  EQU         77,Q                  *EENTS IN EMERG
EIN2  EQU         79,Q                  *EENTS IN GSG ETC.
EIN4  EQU         81,Q                  *EENTS IN ORTHO
OIN0  EQU         85,Q                  *ORTHOS IN EMERG
OIN2  EQU         87,Q                  *ORTHOS IN GSG ETC.
OIN3  EQU         88,Q                  *ORTHOS IN EENT
***************************************
*    OTHER TABLES
***************************************
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*
*   OPERATIONS STATISTICS
 GSGSN EQU        1,T                        *GENERAL SURGERY NUMBERS
 GSGST EQU        2,T                        *GENERAL SURGERY TIME
 EENSN EQU        3,T                        *EENT NUMBERS
 EENST EQU        4,T                        *EENT TIME
 EENSN TABLE      XH$EOPNO,0,1,11
 EENST TABLE      XH$EOPTM,0,60,18
 ORPSN EQU        5,T                        *ORTHOPEDIC NUMBERS
 ORPST EQU        6,T                        *ORTHOPEDIC TIME
 ORPSN TABLE      XH$OOPNO,0,1,11
 ORPST TABLE      XH$OOPTM,0,60,12
 EMTBN EQU        35,T                       *EMERGENGY NUMBERS
 EMTBT EQU        36,T                       *EMERGENGY TIME
 EMTBN TABLE      XH$EMGNO,0,1,15
 EMTBT TABLE      XH$EMGTM,0,30,22
*   EMERGENCY AND DIRECT URGENT ARRIVALS
 EMGDU EQU        37,T
 EMGDU TABLE      XH$EMARR,0,1,32
*   'NO BED' OCCURANCES
 NOBED EQU        38,T
 NOBED TABLE      XH$NOBD,0,1,22
****************************************
*   USER CHAINS
****************************************
*
 ADMMC EQU        46,C                       *MEDICAL ADMISSIONS
 ADMSC EQU        43,C                       *SURGERY ADMISSIONS
 DISCH EQU        47,C                       *DISCHARGE CHAIN
 EMRGC EQU        48,C                       *EMERGENCY OPERATIONS CHAIN
 MALT3 EQU        50,C                       *MEDICAL PATIENTS IN AREA 3
 MALT4 EQU        51,C                       *MEDICAL PATIENTS IN AREA 4
 SLEEN EQU        14,C                       *EENT END SLATE
 SLEW1 EQU        8,C                        *EENT WEEK 1 SLATE
 SLEW2 EQU        9,C                        *EENT WEEK 2 SLATE
 SLEW3 EQU        10,C                       *EENT WEEK 3 SLATE
 SLEW4 EQU        11,C                       *EENT WEEK 4 SLATE
 SLEW5 EQU        12,C                       *EENT WEEK 5 SLATE
 SLEW6 EQU        13,C                       *EENT WEEK 6 SLATE
 SLOEN EQU        21,C                       *ORTHO END SLATE
 SLOW1 EQU        15,C                       *ORTHO WEEK 1 SLATE
 SLOW2 EQU        16,C                       *ORTHO WEEK 2 SLATE
 SLOW3 EQU        17,C                       *ORTHO WEEK 3 SLATE
 SLOW4 EQU        18,C                       *ORTHO WEEK 4 SLATE
 SLOW5 EQU        19,C                       *ORTHO WEEK 5 SLATE
 SLOW6 EQU        20,C                       *ORTHO WEEK 6 SLATE
 XFERC EQU        49,C                       *TRANSFERS' CHAIN
****************************************
*   STORAGES
****************************************
*
*   BEDS PER SERVICE
       STORAGE    S1,165/S2,100/S3,35/S4,75
****************************************
*   FUNCTIONS
****************************************
*
*   DAILY PATIENT ARRIVAL DISTRIBUTIONS
 ARNON FUNCTION   P1,E3                      *NON-SCHEDULABLE ARRIVALS BY SERVICE
1,FN$ANMED/3,FN$ANEEN/4,FN$ANORP
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 ARSCH FUNCTION   P1,E3                    *SCHEDULABLE ARRIVALS BY SERVICE
1,FN$ASMED/3,FN$ASEEN/4,FN$ASORP
 ANMED FUNCTION   RN2,D16                  *MEDICINE NON-SCHEDULABLE
.020,6/.063,7/.136,8/.235,9/.350,10/.466,11/.573,12/.665,13/.744,14
.813,15/.874,16/.924,17/.961,18/.984,19/.996,20/1,21
 ANEEN FUNCTION   RN3,D5                   *EENT NON-SCHEDULABLE
.616,0/.907,1/.959,2/.989,3/1,4
 ANORP FUNCTION   RN4,D7                   *ORTHOPEDIC NON-SCHEDULABLE
.162,0/.324,1/.568,2/.757,3/.919,4/.973,5/1,6
 ASMED FUNCTION   RN2,D9                   *MEDICAL SCHEDULABLE
.205,0/.220,1/.245,2/.310,3/.475,4/.725,5/.890,6/.960,7/1,8
 ASEEN FUNCTION   RN3,D9                   *EENT SCHEDULABLE
.313,0/.376,2/.451,3/.528,4/.619,5/.712,6/.819,7/.940,8/1,9
 ASORP FUNCTION   RN4,D6                   *ORTHOPEDIC SCHEDULABLE
.286,0/.314,1/.429,2/.657,3/.829,4/1,5
*   NUMBER OF DOCTORS PER SERVICE
 1     FUNCTION   RN2,C2                   *SAY 22 MEDICAL DOCTORS, EQUAL USAGE
0,1/1,23
 3     FUNCTION   RN3,C2                   *SAY 10 EENT DOCTORS, EQUAL USAGE
0,1/1,11
 4     FUNCTION   RN4,C2                   *9 ORTHOPEDIC DOCTORS, EQUAL USAGE
0,1/1,10
*   PATIENT DIAGNOSTIC CATEGORY DISTRIBUTIONS
 10    FUNCTION   P1,E3                    *SELECT SERVICE'S FUNCTION
1,FN11/3,FN13/4,FN14
 11    FUNCTION   RN2,D2                   *MEDICINE
.800,1/1,2
 13    FUNCTION   RN3,D2                   *EENT
.788,1/1,2
 14    FUNCTION   RN4,D2                   *CRTHOPEDICS
.759,1/1,2
 20    FUNCTION   P1,E3                    *SELECT SERVICE'S FUNCTION
1,FN21/3,FN23/4,FN24
 21    FUNCTION   RN2,D3                   *MEDICINE
.414,3/.585,4/1,5
 23    FUNCTION   RN3,D3                   *EENT
.033,3/.066,4/1,5
 24    FUNCTION   RN4,D3                   *CRTHOPEDICS
.020,3/.217,4/1,5
*   PATIENT SEX
 30    FUNCTION   P1,E3                    *SELECT SERVICE
1,FN31/3,FN33/4,FN34
 31    FUNCTION   RN2,D2                   *MEDICINE PROPORTIONS IN SEXES
.565,1/1,2
 33    FUNCTION   RN3,D2                   *EENT PROPORTIONS IN SEXES
.500,1/1,2
 34    FUNCTION   RN4,D2                   *CRTHO PROPORTIONS IN SEXES
.535,1/1,2
*   PATIENT AGE GROUP
 41    FUNCTION   RN2,D5                   *MEDICINE MALE AGE GROUP PROPORTIONS
.008,1/.143,2/.445,3/.840,4/1,5
 42    FUNCTION   RN2,D5                   *MEDICINE FEMALE AGE GROUP PROPORTIONS
.008,1/.185,2/.401,3/.743,4/1,5
 45    FUNCTION   RN3,D5                   *EENT MALE AGE GROUP PROPORTIONS
.025,1/.421,2/.696,3/.922,4/1,5
 46    FUNCTION   RN3,D5                   *EENT FEMALE AGE GROUP PROPORTIONS
.025,1/.359,2/.567,3/.853,4/1,5
 47    FUNCTION   RN4,D5                   *ORTHO MALE AGE GROUP PROPORTIONS
.02,1/.45,2/.78,3/.96,4/1,5
 48    FUNCTION   RN4,D5                   *ORTHO FEMALE AGE GROUP PROPORTIONS
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.02,1/.32,2/.525,3/.815,4/1,5
*   PATIENT LENGTH OF STAY DISTRIBUTIONS
 51     FUNCTION    RN2,C17                    *MEDICINE 1ST AGE GROUP
0,1/.121,2/.391,4/.600,6/.737,8/.819,10/.874,12/.933,16/.958,20/.971,24
.984,32/.991,40/.994,48/.997,64/.998,80/.999,96/1,128
 52     FUNCTION    RN2,C17                    *MEDICINE 2ND AGE GROUP
0,1/.125,2/.388,4/.591,6/.717,8/.799,10/.852,12/.911,16/.942,20/.960,24
.979,32/.987,40/.992,48/.995,64/.997,80/.998,96/1,128
 53     FUNCTION    RN2,C17                    *MEDICINE 3RD AGE GROUP
0,1/.007,2/.330,4/.492,6/.617,8/.704,10/.768,12/.855,16/.909,20/.932,24
.965,32/.980,40/.988,48/.995,64/.998,80/.999,96/1,128
 54     FUNCTION    RN2,C17                    *MEDICINE 4TH AGE GROUP
0,1/.005,2/.182,4/.327,6/.430,8/.550,10/.630,12/.742,16/.818,20/.878,24
.926,32/.956,40/.973,48/.985,64/.991,80/.994,96/1,128
 55     FUNCTION    RN2,C17                    *MEDICINE 5TH AGE GROUP
0,1/.005,2/.110,4/.196,6/.291,8/.405,10/.487,12/.613,16/.701,20/.770,24
.852,32/.900,40/.935,48/.960,64/.975,80/.984,96/1,128
 61     FUNCTION    RN3,C15                    *EENT 1ST AGE GROUP
0,1/.073,2/.851,4/.920,6/.949,8/.967,10/.974,12/.986,16/.990,20/.993,24
.995,32/.997,40/.998,48/.999,64/1,80
 62     FUNCTION    RN3,C13                    *EENT 2ND AGE GROUP
0,1/.025,2/.560,4/.870,6/.957,8/.980,10/.989,12/.994,16/.996,20/.997,24
.998,32/.999,40/1,80
 63     FUNCTION    RN3,C12                    *EENT 3RD AGE GROUP
0,1/.032,2/.405,4/.712,6/.863,8/.925,10/.956,12/.982,16/.992,20/.996,24
.999,32/1,40
 64     FUNCTION    RN3,C15                    *EENT 4TH AGE GROUP
0,1/.014,2/.251,4/.561,6/.751,8/.851,10/.912,12/.957,16/.972,20/.981,24
.990,32/.994,40/.996,48/.997,64/1,80
 65     FUNCTION    RN3,C15                    *EENT 5TH AGE GROUP
0,1/.018,2/.136,4/.440,8/.698,8/.840,10/.914,12/.969,16/.982,20/.989,24
.994,32/.996,40/.997,48/.998,64/1,80
 66     FUNCTION    RN4,C14                    *ORTHO 1ST AGE GROUP
0,1/.122,2/.418,4/.568,6/.679,8/.737,10/.781,12/.844,16/.913,20/.952,24
.983,32/.993,40/.997,48/1,64
 67     FUNCTION    RN4,C17                    *ORTHO 2ND AGE GROUP
0,1/.037,2/.248,4/.524,6/.720,8/.796,10/.845,12/.905,16/.926,20/.940,24
.957,32/.972,40/.981,48/.989,64/.994,80/.996,96/1,128
 68     FUNCTION    RN4,C17                    *ORTHO 3RD AGE GROUP
0,1/.028,2/.187,4/.370,6/.532,8/.620,10/.687,12/.783,16/.852,20/.889,24
.944,32/.966,40/.977,48/.989,64/.995,80/.997,96/1,128
 69     FUNCTION    RN4,C17                    *CRTHO 4TH AGE GROUP
0,1/.028,2/.173,4/.302,6/.406,8/.472,10/.523,12/.609,16/.701,20/.766,24
.853,32/.906,40/.936,48/.970,64/.984,80/.990,96/1,128
 70     FUNCTION    RN4,C17                    *ORTHO 5TH AGE GROUP
0,1/.005,2/.035,4/.078,6/.130,8/.171,10/.211,12/.285,16/.392,20/.485,24
.630,32/.722,40/.790,48/.875,64/.924,80/.952,96/1,128
*   PATIENT PREOPERATIVE LOS
 120    FUNCTION    P1,E2                      *SPECIFY BY SERVICE
3,1/4,1
*   TO OBTAIN FRACTION OF PTS NOT ASSIGNED A 'REQUESTED DATE OF ADMISSION'
 140    FUNCTION    P1,E2                      *SELECT SERVICE
3,FN143/4,FN144
 143    FUNCTION    P6,D3                      *EENT
3,500/4,100/5,300
 144    FUNCTION    P6,D3                      *ORTHOPEDICS
3,50/4,100/5,750
*   DAYS TO REQUESTED ADMISSION DATE (FROM NEXT BLOCKED SPOT FOR DR)
 163    FUNCTION    RN1,D2                     *EENT URGENTS
.333,0/1,7
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 164   FUNCTION   RN1,D2                  *EENT SEMI-URGENTS
.333,0/1,7
 165   FUNCTION   RN1,D11                 *EENT ELECTIVES
.060,0/.360,7/.480,14/.640,21/.800,28/.880,35/.920,42/.940,49/.960,56
.980,63/1,70
 168   FUNCTION   RN1,D3                  *ORTHO URGENTS
.25,0/.75,7/1,14
 169   FUNCTION   RN1,D7                  *ORTHO SEMI-URGENTS
.1,0/.3,7/.5,14/.7,21/.8,28/.9,35/1,42
 170   FUNCTION   RN1,D8                  *ORTHO ELECTIVES
.1,0/.2,7/.5,14/.6,21/.7,28/.8,35/.9,42/1,49
*   SURGERY DAYS OF THE WEEK BY DOCTOR
 201   FUNCTION   XH$CHKDR,D5             *EENT
2,1/4,2/6,3/8,4/10,5
 202   FUNCTION   XH$CHKDR,D5             *ORTHOPEDICS
2,1/4,2/6,3/7,4/9,5
*   FUNCTIONS TO DETERMINE HOW MANY QUEUED MEDICAL PATIENTS TO ADMIT
 231   FUNCTION   CH$ADMMC,E3             *FN DEPENDS ON MED QUEUE LENGTH
26,FN232/33,FN233/150,FN234
*   NUMBERS ARE BASED ON REMAINING CAPACITY
 232   FUNCTION   R1,D6                   *SLOW IT DOWN
6,0/8,1/10,2/12,3/15,4/50,5
 233   FUNCTION   R1,D6                   *SUITABLE
6,0/8,3/10,4/12,5/15,6/50,7
 234   FUNCTION   R1,D6                   *SPEED IT UP
6,0/8,5/10,6/12,7/15,8/50,9
*   FOR EMERGENCY PATIENTS
 235   FUNCTION   P14,D4                  *MORNING RESERVE, OWN AREA
1,8/2,0/3,4/4,3
 236   FUNCTION   P14,D4                  *MORNING RESERVE, OTHER AREAS
1,20/2,0/3,7/4,4
 237   FUNCTION   P14,D4                  *NON-MORNING RESERVE, OWN AREA
1,0/2,0/3,0/4,0
 238   FUNCTION   P14,D4                  *NON-MORNING RESERVE, OTHER AREAS
1,0/2,0/3,0/4,0
 239   FUNCTION   P14,D4                  *ANY MORE OFF-SERVICE CAUSE XFER
1,20/2,0/3,7/4,4
*   SCHEDULED PATIENTS PERMITTED PER DAY BY SERVICE
 240   FUNCTION   P1,D2
3,9/4,5
*   SCHEDULED TIME PERMITTED PER DAY BY SERVICE
 241   FUNCTION   P1,D2                   *DEPENDS ON NUMBER OF OR'S
3,840/4,420
*   NUMBER BEFORE TURNAROUNDS (DEPENDS ON NUMBER OF OR'S)
 242   FUNCTION   P1,D2
3,4/4,2
*   DOCTORS PER SERVICE
 243   FUNCTION   P1,D3
1,22/3,10/4,9
*   PROPORTION NOT CANCELLING FOR LONG WAIT
 245   FUNCTION   P1,D2
3,990/4,500
*   PROPORTION OF THOSE ADMITTED NOT GENERATING EMERGENCY OPERATIONS REQUESTS
 247   FUNCTION   P1,D2
3,934/4,838
*   PROPORTION NOT GENERATING INHOSPITAL OPERATIONS REQUESTS
 248   FUNCTION   P1,D2
3,968/4,897
*   PATIENT LENGTH OF SURGERY DISTRIBUTIONS
 261   FUNCTION   RN1,D10                 *EENT 1ST AGE GROUP
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.111,30/.259,35/.444,40/.630,45/.778,50/.852,55/.889,60/.926,70/.963,90
1,110
 262    FUNCTION    RN1,D23                 *EENT 2ND AGE GROUP
.051,25/.153,30/.271,35/.356,40/.424,45/.475,50/.525,55/.576,60/.610,65
.644,70/.678,75/.712,80/.746,85/.780,90/.814,100/.847,110/.881,120
.915,130/.932,140/.949,150/.966,160/.983,170/1,200
 263    FUNCTION    RN1,D17                 *EENT 3RD AGE GROUP
.051,30/.103,40/.154,50/.205,55/.333,60/.410,65/.462,70/.590,75/.641,80
.692,85/.744,90/.795,95/.821,100/.872,115/.923,130/.974,160/1,210
 264    FUNCTION    RN1,D11                 *EENT 4TH AGE GROUP
.042,25/.125,40/.250,50/.417,55/.583,60/.708,65/.792,70/.875,80/.917,90
.958,100/1,120
 265    FUNCTION    RN1,D7                  *EENT 5TH AGE GROUP
.167,30/.333,45/.500,55/.667,60/.833,65/.917,70/1,80
 266    FUNCTION    RN1,D6                  *ORTHO 1ST AGE GROUP
.1,20/.2,30/.4,40/.6,50/.9,60/1,70
 267    FUNCTION    RN1,D14                 *ORTHO 2ND AGE GROUP
.097,30/.161,45/.290,50/.419,55/.516,60/.613,65/.677,70/.742,75/.774,80
.839,90/.903,100/.935,110/.968,120/1,130
 268    FUNCTION    RN1,D17                 *ORTHO 3RD AGE GROUP
.068,15/.136,30/.227,45/.318,50/.409,55/.500,60/.591,65/.682,70/.750,75
.818,80/.864,90/.886,100/.909,115/.932,130/.955,145/.977,160/1,200
 269    FUNCTION    RN1,D12                 *ORTHO 4TH AGE GROUP
.033,30/.067,40/.2C,45/.367,50/.433,60/.533,70/.600,80/.767,90/.833,100
.900,120/.967,135/1,150
 270    FUNCTION    RN1,D11                 *ORTHO 5TH AGE GROUP
.071,30/.143,45/.286,60/.357,75/.429,90/.571,105/.643,120/.714,130
.857,140/.929,180/1,240
****************************************
*   EXPLANATION OF DAILY EVENT PRIORITIES
****************************************
*
*   THE SLATE-UPDATING 'BOOKKEEPER' IS HIGHEST PRIORITY - 21.
*
*   THE DETERMINATION OF ADMISSION REQUESTS TO APPEAR ON THIS DATE IS
*   HIGHEST PRIORITY OF THE PATIENT-RELATED EVENTS INITIATED - 19.
*   A PATIENT BEING GIVEN CHARACTERISTICS AND BEING FILED IS RAISED
*   TO PRIORITY 20 SO THAT IT IS DONE BEFORE WORKING ON ANOTHER.
*
*   DISCHARGES ARE SECOND PRIORITY - 16
*
*   TRANSFERS  ARE NEXT - 14
*
*   MORNING EMERGENCIES ARE NEXT - 12
*
*   THE ADMISSION PROCESSING FOR THIS DATE IS PRIORITY 10. ALL ADMITTED
*   PATIENTS ARE CONSIDERED IN GENERATING EMERGENCY AND INHOSPITAL OPERATIONS
*
*   ALL NON-MORNING EMERGENCIES COME THEN - 6
*
*   OR DATA IS CALCULATED LAST - 2
*
*   A TIMER TRANSACTION COMPLETES EACH DAY - PRIORITY 1
*
****************************************
*   TRANSACTION TO UPDATE SLATE FILE EACH WEEKEND
****************************************
        GENERATE    1,,,1,21,2              *GENERATE SINGLE ENTITY AS BOOKKEEPER
 SUN    ASSIGN      2,6                     *SET PARAMETER 2 TO LOOP TILL SATURDAY
 DAY    ADVANCE     1                       *LET DAY PASS
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      LOOP       2,DAY                  *DECREMENT P2 (UNTIL 0) AND GO TO DAY
*   FIRST THING EACH SATURDAY
      MSAVEVALUE 9-10+,1,1-5,7,MH       *ADD 1 WEEK TO NEXT SURGERY DATES
      ASSIGN     1,V$MOD6               *ADD 1 MOD 6 TO XH$USRSL VIA P1
      SAVEVALUE  USRSL,P1,H             *RESET XH$USRSL
      SAVEVALUE  WEEK,5,H               *HENCE, WORKING 5 WEEKS AWAY
      SAVEVALUE  PTFWK,V$APRWK,H        *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
      SAVEVALUE  TMFWK,XH$PTFWK,H       *SET THIS THE SAME
      SAVEVALUE  TMFWK+,1,H             *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
      MSAVEVALUE 9-10,XH$PTFWK,1-5,0,MH *FOR WHOLE WEEK, # PTS SET TO 0
      MSAVEVALUE 9-10,XH$TMFWK,1-5,0,MH *FOR WHOLE WEEK,TIME SET TO 0
      SAVEVALUE  MDATE,XH$PWEEK,H       *FIRST DAY OF PRESENT WEEK TO MDATE
      SAVEVALUE  MDATE+,47,H            *FRIDAY OF WEEK TO BE BROUGHT IN
      ASSIGN     1,4                    *P1=HIGHEST SERVICE
TCMOV TEST NE    P1,2,NDAY              *DON'T DO SERVICE 2
      UNLINK     V$SEUSC,ONFIL,ALL,BV$SIXWK *UNLINK THAT WEEK TO FILE
      LOOP       1,TOMOV                *DECREMENT SERVICE NUMBER AND REPEAT
NDAY  SAVEVALUE  PWEEK+,7,H             *FIRST DAY OF NEW SLATE WEEK
      ADVANCE    1                      *OVER SATURDAY
      TRANSFER   ,SUN                   *ANOTHER WEEK...GO TO SUNDAY
*   BRINGING APPROPRIATE PART OF END CHAIN TO 5TH WEEK CHAIN
ONFIL SAVEVALUE  CHKDR,P5,H             *DOCTOR TO CHECK FOR THIS PATIENT
      SAVEVALUE  WEEK,5,H               *WORKING 5 WEEKS AWAY
      ASSIGN     15,1,V$SGYDW           *P15=DAY OF WEEK FOR THAT DOCTOR
      SAVEVALUE  PTFWK,V$APRWK,H        *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
      SAVEVALUE  TMFWK,XH$PTFWK,H       *SET THIS THE SAME
      SAVEVALUE  TMFWK+,1,H             *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
*   IS THERE SPACE ON THAT DAY?
      ASSIGN     13,MH*V$OFFSL(XH$PTFWK,P15) *P13=PTS FOR DATE BEING CHECKED
      ASSIGN     13+,1                  *P13=PTS IF THIS ONE ADDED
      ASSIGN     14,MH*V$OFFSL(XH$TMFWK,P15) *P14=TIME FOR DATE BEING CHECKED
      ASSIGN     14+,P11                *P14=TIME IF THIS ONE ADDED
      TEST NE    BV$TRYDA,1,DAYES       *TESTING FOR SPACE
      MARK       13                     *NO SPACE, MARK PRESENT DAY
      TEST GE    V$HLONG,7,NLONG        *WAITED OVER 7 WEEKS UNSUCCESSFULLY?
      TRANSFER   .FN245,,NLONG          *YES, MANY CANCEL
      SAVEVALUE  CANCL+,1,H             *ONE MORE
      SAVEVALUE  MSRVC,P1,H             *WANT SERVICE TO MATCH
      SAVEVALUE  MDGEN,P2,H             *WANT DATE GENERATED TO MATCH
      SAVEVALUE  MDATE,P3,H             *WANT ADM DATE TO MATCH
      SAVEVALUE  MLOST,P9,H             *ALSO MATCH LENGTH OF STAY
      SAVEVALUE  MLOSG,P11,H            *ALSO MATCH LENGTH OF SURGERY
      UNLINK     ADMSC,OFFFQ,1,BV$MACHR,,FAILD *TAKE OFF ADM CHAIN
      TRANSFER   ,DSPOS                 *REMOVE FROM MODEL
OFFFQ DEPART     V$WAITQ                *BETTER TAKE FROM WAIT QUEUE
      TRANSFER   ,DSPOS                 *REMOVE FROM MODEL
NLONG SAVEVALUE  MDATE,P3,H             *NOT TOO LONG, ADM DATE TO MATCH
      SAVEVALUE  MSRVC,P1,H             *WANT SERVICE TO MATCH
      SAVEVALUE  MDGEN,P2,H             *WANT DATE GENERATED TO MATCH
      SAVEVALUE  MLOST,P9,H             *ALSO MATCH LENGTH OF STAY
      SAVEVALUE  MLOSG,P11,H            *ALSO MATCH LENGTH OF SURGERY
      UNLINK     ADMSC,UPWK,1,BV$MACHR,,FAILD *GET PT OFF ADM CHAIN
      ASSIGN     3+,7                   *ADD 1 WEEK TO ADMISSION DATE
      ASSIGN     4+,7                   *ADD 1 WEEK TO SURGERY DATE
      LINK       V$SEUSC,6              *BACK ON SLATE END CHAIN
UPWK  ASSIGN     3+,7                   *ADD 1 WEEK TO ADM DATE
      ASSIGN     4+,7                   *ADD 1 WEEK TO SURGERY DATE
      LINK       ADMSC,3                *BACK ON ADMISSION CHAIN
*   THERE IS SPACE FOR THESE
DAYES MSAVEVALUE V$OFFSL+,XH$PTFWK,P15,1,MH *ADD 1 TO PTS THAT WEEK/DOW/SERVICE
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          MSAVEVALUE V$OFFSL+,XH$TMFWK,P15,P11,MH *ADD SURGERY TIME SIMILARLY
          TEST GE    MH*V$OFFSL(XH$PTFWK,P15),FN242,PUT1 *2+ PTS PER OR SLATED?
          MSAVEVALUE V$OFFSL+,XH$TMFWK,P15,15,MH *ADD TURNAROUND BEFORE NEXT PT
   PUT1   LINK       V$SLUSC,5            *PUT ON SLATE USER CHAIN
*****************************************
*    PATIENT GENERATION SECTION
*****************************************
*
*    EACH DAY AN ENTITY IS GENERATED AND MARKED WITH THE TIME.
*    IT IS THEN SPLIT INTO THE APPROPRIATE NUMBER OF PATIENTS FOR EACH SERVICE
*    FOR THAT DAY. THESE PATIENTS HAVE PARAMETERS AS FOLLOWS:
*        P1          SERVICE AS FOLLOWS:
*                    1-MEDICINE
*                    2-GENERAL SURGERY
*                    3-E.E.N.T.
*                    4-ORTHOPEDICS
*        P2          TIME (DAY) OF ADMISSION REQUEST
*        P3          TIME OF ADMISSION
*        P4          TIME OF (NEXT) OPERATION
*        P5          NUMBER OF DOCTOR
*                    EG. 1-9 FOR ORTHOPEDICS
*        P6          PATIENT DIAGNOSTIC CATEGORY:
*                    1-EMERGENT
*                    2-DIRECT URGENT
*                    3-URGENT
*                    4-SEMI-URGENT
*                    5-ELECTIVE
*        P7          SEX:
*                    1-MALE
*                    2-FEMALE
*        P8          AGE GROUP:
*                    1- 0-14
*                    2- 15-34
*                    3- 35-54
*                    4- 55-74
*                    5- 75 OR ABOVE
*        P9          LENGTH OF STAY
*        P10         PRE-OPERATIVE LOS
*        P11         LENGTH OF (NEXT) SURGERY
*        P12         REQUESTED ADMISSION DATE (SURG.DATE FOR SURGICAL SERVICES)
*        P13         WORK...FOR DISCHARGES OR TRANSFERS, TIME OF DISCHARGE
*        P14         WORK...FOR TRANSFER AND DISCHARGE PATIENTS, AREA IN
*        P15         WORK
*
*
          GENERATE   1,,,,19,15           *DAILY,FIRST THING DONE RE. PATIENTS
          ASSIGN     1,4                  *P1=HIGHEST HOSPITAL SERVICE
          MARK       2                    *P2=TIME OF ADMISSION REQUEST
   REAL   TEST NE    P1,2,LOOP1           *DON'T DO SERVICE 2
          SPLIT      FN$ARNON,PTS1        *MAKE NON-SCHEDULABLE REQUESTS
          SPLIT      FN$ARSCH,PTS2        *MAKE SCHEDULABLE REQUESTS
   LOOP1  LOOP       1,REAL               *DECREMENT SERVICE AND GO TO REAL
   OUT    TERMINATE                       *REMOVE XACT GENERATING PTS FROM MODEL
*    SEGMENT ASSIGNING CHARACTERISTICS TO PATIENTS
   PTS1   ASSIGN     6,1,10               *P6=PT DIAGNOSTIC CATEGORY (VIA FN10)
          TRANSFER   ,CHAR                *GO ASSIGN OTHER CHARACTERISTICS
   PTS2   ASSIGN     6,1,20               *P6=PT DIAGNOSTIC CATEGORY (VIA FN20)
   CHAR   ASSIGN     5,1,P1               *P5=NUMBER OF PATIENT'S DOCTOR (VIA FN*1)
          ASSIGN     7,1,30               *P7=PATIENT SEX (VIA FN30)
          ASSIGN     8,1,V$ADIST          *P8=PATIENT AGE GROUP (VIA FN*V$ADIST)
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      ASSIGN      9,1,V$LDIST          *P9=PATIENT'S L OF STAY (VIA FN*V$LDIST)
      MSAVEVALUE  P1+,P6,1,1,MH        *ADD 1 TO # GENERATED (SERVICE/CATEGORY)
      MSAVEVALUE  P1+,6,1,1,MH         *ADD 1 TO # GENERATED (BY SERVICE)
      TEST GE     P6,3,EMERG           *SEND EMERG AND DIRECT URGENTS TO HANDLE
      PRIORITY    V$CTPRI,BUFFER       *PROCEED IN ORDER BY CATEGORY
      PRIORITY    20                   *RAISE TO PROPER CATEGORY
      QUEUE       V$WAITO              *GATHER WAIT TIME STATS (SERVICE/CATEGORY
      TEST NE     P1,1,MEDIC           *SEND MEDICAL REQUESTS TO HANDLE
      TRANSFER    ,SURG                *SEND SURGICAL REQUESTS TO HANDLE
*****************************************
*   SURGICAL REQUEST HANDLING
*****************************************
*
*   CONSIDER E.E.N.T.,ORTHOPEDICS,UROLOGY, AND GYNECOLOGY TO BE PROPERLY BLOCK
*   BOOKED BY DAY FOR DOCTOR, GENERAL SURGERY BY SUB-SERVICE, AND NEURO/PLASTICS
*   NOT AT ALL.
*
BLNOT TERMINATE                        *TEMPORARY
BLSRV TERMINATE                        *TEMPORARY
SURG  ASSIGN      10,1,120             *P10=PRE-OPERATIVE LOS (VIA FN120)
      TEST GE     P10,P9,CANDO         *IF PRE-OP LOS IS 'L' LOS, CAN BE DONE
      ASSIGN      9,P10                *IF NOT, PUT PRE-OP LOS IN LOS SPOT
      ASSIGN      9+,1                 *AND ADD 1
CANDO ASSIGN      11,1,V$SDIST         *P11=LENGTH OF NEXT SURG (VIA FN*V$SDIST)
      TEST G      P1,2,BLSRV           *FOR SERVICE 2 GO BLOCK BOOK BY A/B/C
      TEST L      P1,7,BLNOT           *FOR SERVICE 7 GO TREAT AS NOT BLOCK BOOK
      SAVEVALUE   CHKDR,P5,H           *DOCTOR TO CHECK IN XH$CHKDR
      TRANSFER    .FN140,,NOREQ        *XFER PROPORTION NOT REQUESTING A DATE
*   ASSIGN A REQUESTED DATE TO AN APPROPRIATE PROPORTION OF PATIENTS
      ASSIGN      12,1,V$DSTRQ         *P12=DAYS TO REQ. DATE FROM NEXT BLOCK
      ASSIGN      13,1,V$SGYDW         *P13=DOCTOR'S DAY OF WEEK FOR SURGERY
      ASSIGN      12+,MH*V$OFFSL(1,P13) *P12=REQUESTED DATE OF SURGERY
      MARK        13                   *IS REQ.DATE POSSIBLE? P13=PRESENT TIME
      ASSIGN      13+,P10              *P13=EARLIEST POSS DATE FOR PRE-OP LOS
      TEST G      P13,P12,FEAS         *IF THIS DATE 'LE' REQ. DATE O.K.
      ASSIGN      12+,7                *OTHERWISE INCREMENT REQ. DATE SO O.K.
FEAS  SAVEVALUE   CHECK,P12,H          *CHECK DATE (FOR SURGERY) FROM REQ. DATE
      TRANSFER    ,TRY                 *GO TRY TO PLACE ON SLATE
*   NO PARTICULAR DATE REQUESTED FOR THESE PATIENTS
NOREQ MARK        13                   *P13=PRESENT TIME
      ASSIGN      15,0                 *ZERO P15
      ASSIGN      15-,P13              *P15=-PRESENT TIME
      ASSIGN      14,1,V$SGYDW         *P14=DOCTOR'S DAY OF WEEK OF SURGERY
      ASSIGN      13,MH*V$OFFSL(1,P14) *NEXT DATE OF SURGERY FOR DOCTOR
      ASSIGN      15-,P10              *P15=-VE OF NEXT POSSIBLE TIME
      ASSIGN      15+,P13              *P15=FREE MARGIN TO NEXT SLATED DAY
      TEST L      P15,0,AFEAS          *IF NEGATIVE, MUST FIX
      ASSIGN      13+,7                *INCREASE BY 1 WEEK
AFEAS ASSIGN      15,0                 *CLEAR NUMBERS FROM P15
      ASSIGN      13+,7                *START CHECKING SPOT 1 WEEK FR EARLIEST
      SAVEVALUE   CHECK,P13,H          *CHECK DATE WAS COMPUTED IN P13
*
*   SEGMENT READY TO TRY A PARTICULAR DAY
*   AT THIS POINT, XH$CHKDR AND XH$CHECK MUST BE SET
*
TRY   SAVEVALUE   WEEK,V$CWEEK,H       *WEEK CHECKED DETERMINED FROM CHECK DATE
      TEST GE     XH$WEEK,6,LOOK       *IF 'L' 6 WEEKS AWAY, LOOK AT SLATE
*  THESE ONES 6 OR MORE WEEKS AWAY, PUT ON SLATE END
      ASSIGN      4,XH$CHECK           *P4=CHECK DATE FOR SURGERY
      ASSIGN      3,P4                 *SAME TO P3
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        ASSIGN      3-,P10                  *P3=ADMISSION DATE (SURG - PREOP)
        TEST LE     P6,0,POS1               *WANT POSITIVE CATEGORY
        ASSIGN      13,P6                   *PUT ANY NEGATIVE CATEGORY IN P13
        ASSIGN      6,0                     *SET TO 0
        ASSIGN      6-,P13                  *NOW POSITIVE
POS1    SPLIT       1,SLCH1                 *CREATE COPY FOR SLATE CHAIN
        TRANSFER    ,FILE                   *ORIGINAL TO ADMISSION FILE
SLCH1   LINK        V$SEUSC,6               *LINK TO SLATE-END CHAIN BY DOCTOR
*   FOR THESE MUST LOOK AT DESIRED SPOT ON SLATE
LOOK    ASSIGN      15,1,V$SGYDW            *P15=SURGERY DOW FOR DOCTOR
        SAVEVALUE   PTFWK,V$APRWK,H         *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
        SAVEVALUE   TMFWK,XH$PTFWK,H        *SET THIS THE SAME
        SAVEVALUE   TMFWK+,1,H              *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
        ASSIGN      13,MH*V$OFFSL(XH$PTFWK,P15) *P13=PTS FOR DATE BEING CHECKED
        ASSIGN      13+,1                   *P13=PTS IF THIS ONE ADDED
        ASSIGN      14,MH*V$OFFSL(XH$TMFWK,P15) *P14=TIME FOR DATE BEING CHECKED
        SAVEVALUE   NOWTM,P14,H             *TIME BEFORE A BUMP
        ASSIGN      14+,P11                 *P14=TIME IF THIS ONE ADDED
        SAVEVALUE   CHKTM,P11,H             *SETTING SURGERY TIME TO TRY TO FIND
        TEST NE     BV$TRYDA,1,GOTDA        *IF TRUE, THE DAY IS GOOD
        TEST LE     P6,3,NOTUR              *UNLESS P6 IS 3 (OR SET NEG) NOT URGENT
*
*   THE FOLLOWING SECTION DEALS WITH URGENT PATIENTS
*
        TEST GE     XH$WEEK,2,USOON         *IF TRYING 'L' 2 WEEKS AWAY, DO SOON
*   URGENTS OVER 2 WEEKS AWAY TRY TO BUMP
        UNLINK V$SLUSC,BUMPD,1,BV$BUMPE,,NOE *O/W TRY TO BUMP ELECTIVE OF THIS DR
        TRANSFER    ,GOTDA                  *PUT THIS ONE ON IN HIS PLACE
NOE     UNLINK      V$SLUSC,BUMPD,1,BV$BUMPS,,NOS *NO EL - TRY TO BUMP SEMI-URGENT
        TRANSFER    ,GOTDA                  *PUT THIS ONE ON IN HIS PLACE
NOS     SAVEVALUE   CHECK+,7,H              *NOONE TO BUMP, SO TRY 1 WEEK LATER
        TRANSFER    ,TRY                    *GO TRY AGAIN
*   THESE TO BE TREATED AS URGENTS FOR WITHIN 2 WEEKS
USOON MARK          13                      *START CHECKING AT EARLIEST POSSIBLE TIME
        ASSIGN      13+,1                   *TRY TOMORROW ADM AT EARLIEST
        ASSIGN      13+,P10                 *NOW HAVE EARLIEST DAY OF SURGERY
        TEST LE     P13,MH*V$OFFSL(1,5),NEWK *DATE BY THIS FRIDAY?
THWK    SAVEVALUE   WEEK,0,H                *BY FRIDAY, SO IT IS THIS WEEK
        TRANSFER    ,WANTD                  *WANT TO FIND A DOCTOR
NEWK    TEST L      V$ENDWK,3,PROPR         *WAS DATE SET ON WEEKEND?
        ASSIGN      13,XH$PWEEK
        ASSIGN      13+,8                   *YES, SO SET TO NEXT MONDAY
PROPR SAVEVALUE     WEEK,1,H                *HAVE PROPER DATE NEXT WEEK
WANTD SAVEVALUE     CHECK,P13,H             *CHECK DATE IS EARLIEST POSSIBLE
*   HAVE DATE, FIND CORRESPONDING DOCTOR
        SAVEVALUE   CHKDR,1,H               *COULD 1ST DOCTOR POSSIBLY DO?
GETDA ASSIGN        15,1,V$SGYDW            *FIND THIS DOCTOR'S DAY OF THE WEEK
        ASSIGN      14,MH*V$OFFSL(1,P15)    *NEXT DAY OF SURGERY FOR THAT DOCTOR
        TEST NE     V$TRYDR,0,DAYOK         *TO DAYOK IF THIS ONE MIGHT DO
        SAVEVALUE   CHKDR+,1,H              *TRY NEXT DOCTOR
        TRANSFER    ,GETDA                  *GO TO GET HIS DAY
*   DATE AND DOCTOR CORRESPOND, SEE IF THE DAY IS OK
DAYOK SAVEVALUE     PTFWK,V$APRWK,H         *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
        SAVEVALUE   TMFWK,XH$PTFWK,H        *SET THIS THE SAME
        SAVEVALUE   TMFWK+,1,H              *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
        ASSIGN      13,MH*V$OFFSL(XH$PTFWK,P15) *P13=PTS FOR DATE BEING CHECKED
        ASSIGN      13+,1                   *PTS IF THIS ONE ADDED
        ASSIGN      14,MH*V$OFFSL(XH$TMFWK,P15) * P14=TIME FOR THAT DATE
        ASSIGN      14+,P11                 *TIME IF THIS ONE ADDED
        TEST NE     BV$TRYDA,1,GOTDA        *IF TRUE, GOT DAY
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       TEST NE    P15,5,WKDON           *IF THAT WAS FRIDAY, WEEK DONE
 NEWDR SAVEVALUE  CHKDR+,1,H            *ADD 1 TO CHECKED DOCTOR
       ASSIGN     15,1,V$SGYDW          *P15=SURGERY DOW OF THIS DOCTOR
       ASSIGN     14,MH*V$OFFSL(1,P15)  *NEXT DATE OF SURGERY FOR THAT DOCTOR
       TEST NE    V$DASAM,0,NEWDR       *IF THIS DR ON SAME DAY GO FOR ANOTHER
       SAVEVALUE  CHECK+,1,H            *TO TRY DAY LATER
       TRANSFER   ,DAYOK                *GO SEE IF THIS DAY IS OK
 WKDON SAVEVALUE  WEEK+,1,H             *TRY NEXT WEEK
*    TREAT SPECIALLY IF THIS IS TOO FAR AWAY
       TEST GE    XH$WEEK,3,CLOS1       *ARE THERE NO SPOTS NEARBY?
       SAVEVALUE  CHKDR,P5,H            *NO, GET PROPER DOCTOR AGAIN
       ASSIGN     15,1,V$SGYDW          *HIS DAY OF THE WEEK FOR SURGERY
       SAVEVALUE  CHECK,MH*V$OFFSL(1,P15),H *HIS NEXT SURGERY DAY
       SAVEVALUE  CHECK+,14,H           *2 WEEKS AWAY
       TRANSFER   ,TRY                  *HE WILL NOW BUMP ANOTHER
*    STILL CLOSE ENOUGH
 CLOS1 SAVEVALUE  CHECK+,3,H            *ADVANCE DAY FRIDAY TO MONDAY
       SAVEVALUE  CHKDR,1,H             *START AGAIN WITH FIRST DOCTOR
       ASSIGN     15,1                  *THIS DOCTOR'S DAY OF THE WEEK
       TRANSFER   ,DAYOK                *GO SEE IF THE DAY IS OK
*
*    THE FOLLOWING SECTION DEALS WITH NON-URGENT PATIENTS
*
 NOTUR SAVEVALUE  CHECK+,7,H            *FOR SEMI-U AND EL, TRY 1 WEEK LATER
       TRANSFER   ,TRY                  *GO TRY AGAIN
*
*    BUMPED PATIENTS ARE HANDLED HERE
*
 BUMPD SAVEVALUE  CHECK,P4,H            *DAY BUMPED PT STARTED FROM
       SAVEVALUE  CHKDR,P5,H            *DR THIS PATIENT WAS SLATED FOR
       ASSIGN     15,1,V$SGYDW          *THAT DOCTOR'S DAY OF THE WEEK
       SAVEVALUE  PTFWK,V$APRWK,H       *IDENTIFY ROW REMOVED FROM
       SAVEVALUE  TMFWK,XH$PTFWK,H      *SET THIS THE SAME
       SAVEVALUE  TMFWK+,1,H            *IDENTIFY ROW FOR TIME REMOVED
       TEST GE    MH*V$OFFSL(XH$PTFWK,P15),FN242,NRTRN *1 OR MORE PER OR THERE?
       MSAVEVALUE V$OFFSL-,XH$TMFWK,P15,15,MH *REMOVE TURNAROUND WHICH FOLLOWS
 NRTRN MSAVEVALUE V$OFFSL-,XH$PTFWK,P15,1,MH *REMOVE PATIENT
       MSAVEVALUE V$OFFSL-,XH$TMFWK,P15,P11,MH *REMOVE HIS TIME
       SAVEVALUE  CHECK+,7,H            *TRY 1 WEEK FROM THAT SPOT
       SAVEVALUE  MDATE,P3,H            *ADM DATE (FOR MATCHING FROM ADM CHAIN)
       SAVEVALUE  MSRVC,P1,H            *WANT SERVICE TO MATCH
       SAVEVALUE  MDGEN,P2,H            *WANT DATE GENERATED TO MATCH
       SAVEVALUE  MLOST,P9,H            *ALSO MATCH LENGTH OF STAY
       SAVEVALUE  MLOSG,P11,H           *ALSO MATCH LENGTH OF SURGERY
       UNLINK     ADMSC,TRY,1,BV$MACHR,,FAILD *GET PT OFF ADMISSION CHAIN
*    THEN GO TRY IT FOR LATER WEEK
       TRANSFER   ,DSPOS                *THIS COPY OF PT NOT NEEDED
*
*    PATIENTS HERE HAVE GOTTEN A DAY OK FOR SURGERY
*
 GOTDA ASSIGN     4,XH$CHECK            *SURGERY DATE TO P4
       ASSIGN     3,P4                  *SAME TO P3
       ASSIGN     3-,P10                *P3=ADMISSION DATE (SUBTR PRE-OP)
       ASSIGN     15,1,V$SGYDW          *P15=DOCTOR'S SURGERY DOW
       SAVEVALUE  PTFWK,V$APRWK,H       *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
       SAVEVALUE  TMFWK,XH$PTFWK,H      *SET THIS THE SAME
       SAVEVALUE  TMFWK+,1,H            *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
       MSAVEVALUE V$OFFSL+,XH$PTFWK,P15,1,MH *ADD 1 TO PATIENTS SLATED THERE
       MSAVEVALUE V$OFFSL+,XH$TMFWK,P15,P11,MH *ADD SURGERY TIME TO THAT SLATED
       TEST GE    MH*V$OFFSL(XH$PTFWK,P15),FN242,PUT2 *2+ PER OR SLATED THERE?
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        MSAVEVALUE V$OFFSL+,XH$TMFWK,P15,15,MH *ADD TURNAROUND BEFORE NEXT PT
 PUT2   TEST LE    P6,0,POS              *WANT POSITIVE CATEGORY
        ASSIGN     13,P6                 *PUT ANY NEGATIVE CATEGORY IN P13
        ASSIGN     6,0                   *SET TO 0
        ASSIGN     6-,P13                *NOW POSITIVE
 POS    SPLIT      1,SLCH2               *CREATE COPY FOR SLATE CHAIN
        TRANSFER   ,FILE                 *ORIGINAL TO ADMISSION FILE
 SLCH2  LINK       V$SLUSC,5             *PUT ON SLATE CHAIN BY DOCTOR
*    PATIENTS HERE ARE FILED ON ADMISSION QUEUE
 FILE   LINK       ADMSC,3               *ON ADMISSION CHAIN BY DATE
****************************************
*    MEDICAL REQUEST HANDLING
****************************************
*
*    PUT THESE REQUESTS ONTO THE MEDICAL ADMISSIONS CHAIN
*
 MEDIC  LINK       ADMMC,FIFO            *ONTO MEDICAL ADMISSION CHAIN
****************************************
*    TRANSACTION TO INSTIGATE ADMISSIONS
****************************************
*
*    FOR SURGICAL ADMISSIONS, ADMIT ALL SCHEDULED FOR TODAY (ACCORDING
*    TO THEIR SLATE). MEDICAL ADMISSIONS GET SPECIFIED NUMBER OF
*    REMAINING BEDS. LAST FEW ARE SAVED FOR EMERGENCIES.
*
        GENERATE   1,,,,10               *SINGLE TRANSACTION PER DAY TO INSTIGATE
        MARK       3                     *TODAY'S DATE IN P3
        UNLINK     ADMSC,ADMS,ALL,3      *ALL SURG. ADMISSIONS TODAY TO ADMS
        ASSIGN     1,FN231               *NUMBER MEDS TO ADMIT
        UNLINK     ADMMC,ADMM,P1         *ADMIT MEDICAL PATIENTS
        TERMINATE                        *REMOVE INSTIGATING TRANSACTION
***************************************
*    SURGERY ADMISSION PATH
***************************************
*
*    FOR NOW, ALLOW ONLY INTO A BED OF THE PROPER SERVICE AREA, IGNORING SEX
*    BASED ON AVERAGE NUMBERS ENTERING EMERGENCY AND INHOSPITAL OPERATIONS
*    PER DAY, NOW GENERATE THESE REQUESTS. SAY EMERGENCIES ARE NEXT DAY,
*    INHOSPITAL REQUESTS AS SOON AS POSSIBLE FROM 2 DAYS AWAY.
*
 ADMS   GATE LR    WAIT                  *ALLOWED TO BE PROCESSED?
        TEST L     R*1,1,AOK             *ROOM IN SERVICE'S BEDS?
        SAVEVALUE  NOBD+,1,H             *ONE MORE 'NO BED'
        ASSIGN     13,P6                 *CATEGORY IN P13
        ASSIGN     6,0                   *WANT TO SET NEGATIVE
        ASSIGN     6-,P13                *NOW NEG. PROCESSED AS URGENT
*    'NO BEDS' TRY OVER
        ASSIGN     13,XH$PWEEK           *FIRST DAY OF PRESENT WEEK IN P13
        ASSIGN     13+,7                 *ADVANCE THAT TO NEXT WEEK
        LOGIC S    WAIT                  *STOP FURTHER ADMISSIONS NOW
        PRIORITY   19,BUFFER             *FINISH WITH OTHERS FIRST
        PRIORITY   20                    *RESTORE PRIORITY
        LOGIC R    WAIT                  *ALLOW FURTHER ADMISSIONS NOW
*    NEED TO LOCATE THEM ON SURGERY SLATE
        TEST L     P13,P4,THSWK          *WHICH WEEK SURGERY? THIS OR NEXT
        SAVEVALUE  WEEK,1,H              *CHECK 1 WEEK AWAY FOR SURGERY TIME
        TRANSFER   ,OFFSG                *NEED PT OFF SURGERY CHAIN
 THSWK  SAVEVALUE  WEEK,0,H              *CHECK ON THIS WEEK'S SLATES
 OFFSG  SAVEVALUE  MDATE,P3,H            *FIRST, TAKE DATE TO MATCH
        SAVEVALUE  MSRVC,P1,H            *WANT SERVICE TO MATCH
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        SAVEVALUE  MDGEN,P2,H            *WANT DATE GENERATED TO MATCH
        SAVEVALUE  MLOST,P9,H            *ALSO LENGTH OF STAY
        SAVEVALUE  MLOSG,P11,H           *FINALLY, LENGTH OF SURGERY
        UNLINK     V$SLUSC,DSPOS,1,BV$MACHR,,FAILO *GET PT OFF SURGERY CHAIN
        SAVEVALUE  CHKDR,P5,H            *DR THIS PATIENT WAS SLATED FOR
        ASSIGN     15,1,V$SGYDW          *THAT DOCTOR'S DAY OF THE WEEK
        SAVEVALUE  PTFWK,V$APRWK,H       *IDENTIFY ROW REMOVED FROM
        SAVEVALUE  TMFWK,XH$PTFWK,H      *SET THIS THE SAME
        SAVEVALUE  TMFWK+,1,H            *IDENTIFY ROW FOR TIME REMOVAL
        TEST GE    MH*V$OFFSL(XH$PTFWK,P15),FN242,NRMTN *2+ PER OR THERE?
        MSAVEVALUE V$OFFSL-,XH$TMFWK,P15,15,MH *REMOVE TURNAROUND WHICH FOLLOWS
  NRMTN MSAVEVALUE V$OFFSL-,XH$PTFWK,P15,1,MH *REMOVE PATIENT
        MSAVEVALUE V$OFFSL-,XH$TMFWK,P15,P11,MH *REMOVE HIS TIME
        ASSIGN     4+,7                  *ADD 1 WEEK TO ATTEMPTED OPERATION DATE
        SAVEVALUE  CHECK,P4,H            *PUT THIS DATE IN CHECK DATE
        TRANSFER   ,TRY                  *GO TRY, SAME RULES AS NEW REQUESTS
*   IF THERE IS A BED...
  ACK   LOGIC S    WAIT                  *NO MORE ADMISSIONS JUST NOW
        PRIORITY   10,BUFFER             *RESET PRIORITY LEVEL
        DEPART     V$WAITQ               *LEAVE WAITING TIME QUEUE
*   GENERATE EMERGENCY AND INHOSPITAL OPERATION REQUESTS
        TRANSFER   .FN247,,NOEMG         *SEND PROPORTICN NOT GENERATING EMERG OP
        SPLIT      1,NOEMG               *OBTAIN ENTITY TO FOLLOW THIS PATH
        MARK       4                     *PRESENT DAY IN P4
        ASSIGN     4+,1                  *HENCE EMERG OP TOMORROW
        TEST GE    P9,2,DSPOS            *IGNORE IF LOS 'L' 2 DAYS
        ASSIGN     11,1,V$SDIST          *P11=LENGTH OF EMERG SURGERY
        LINK       EMRGC,4               *PUT ON EMERGENCY CHAIN FOR TOMORROW
  NOEMG TRANSFER   .FN248,,NOINH         *SEND THE PROPORTION NOT PLACING INH REQ
        SPLIT      1,NOINH               *GET ENTITY TO EFFECT INHOSPITAL REQUEST
        ASSIGN     11,1,V$SDIST          *P11=LENGTH OF SURGERY
  INHRQ MARK       13                    *PRESENT DAY IN P13
        ASSIGN     13+,2                 *EARLIEST POSS DAY 2 AWAY
        TEST GE    P9,3,DSPOS            *IGNORE IF LOS 'L' 3 DAYS
        TEST LE    P13,MH*V$OFFSL(1,5),NEWEK *DATE BY THIS FRIDAY?
        SAVEVALUE  WEEK,0,H              *YES, SO IT IS THIS WEEK
        TRANSFER   ,WONTD                *WANT TO FIND A DOCTOR
  NEWEK TEST L     V$ENDWK,3,PROPE       *WAS DATE SET CN WEEKEND?
        ASSIGN     13,XH$PWEEK
        ASSIGN     13+,8                 *YES, SO SET TO NEXT MONDAY
  PROPE SAVEVALUE  WEEK,1,H              *HAVE PROPER DATE NEXT WEEK
  WONTD SAVEVALUE  CHECK,P13,H           *THIS GIVES CHECK DATE
*   HAVE DATE, FIND CORRESPONDING DOCTOR
        SAVEVALUE  CHKDR,1,H             *CAN 1ST DOCTOR POSSIBLY DO
  GETSG ASSIGN     15,1,V$SGYDW          *FIND THIS DR'S DAY OF WEEK
        ASSIGN     14,MH*V$OFFSL(1,P15)  *FIND HIS NEXT SURGERY DAY
        TEST NE    V$TRYDR,0,DAYKO       *IF HIS TIME IS OK TO CHECK, TO DAYKO
        SAVEVALUE  CHKDR+,1,H            *OTHERWISE, TRY NEXT DOCTOR
        TRANSFER   ,GETSG                *GO TO GET HIS DAY
*   DATE AND DOCTOR CORRESPOND, SEE IF THE DAY IS OK
  DAYKO SAVEVALUE  PTFWK,V$APRWK,H       *IDENTIFY ROW FOR APPROPRIATE WEEK'S PTS
        SAVEVALUE  TMFWK,XH$PTFWK,H      *SET THIS THE SAME
        SAVEVALUE  TMFWK+,1,H            *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
        ASSIGN     13,MH*V$OFFSL(XH$TMFWK,P15) *P13=TIME FOR THAT DAY
        ASSIGN     13+,P11               *ADD TIME OF THIS ONE TOO
        TEST G     P13,FN241,GTDAY       *GET DAY IF TIME OK THERE
        TEST NE    P15,5,WKDUN           *WEEK DONE IF THAT WAS FRIDAY
  NWDOC SAVEVALUE  CHKDR+,1,H            *ADD 1 TO CHECKED DOCTOR
        ASSIGN     15,1,V$SGYDW          *DR'S SURGERY DAY OF THE WEEK IN P15
        ASSIGN     14,MH*V$OFFSL(1,P15)  *NEXT DAY OF SURGERY FOR THAT DOCTOR
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       TEST NE     V$DASAM,0,NWDOC       *GO FOR ANOTHER IF THIS OR SAME DAY
       SAVEVALUE   CHECK+,1,H            *TO TRY DAY LATER
       TRANSFER    ,DAYKO                *GO SEE IF THIS DAY IS OK
*   PATIENTS HERE HAVE GOTTEN A DAY FOR THEIR INHOSPITAL SURGERY
 WKDUN SAVEVALUE   WEEK+,1,H             *TRY NEXT WEEK
*   TREAT SPECIALLY IF TOO FAR AWAY
       TEST GE     XH$WEEK,2,CLOS2       *ARE THERE NO SPOTS NEARBY?
       MARK        4                     *NO, SO MAKE THIS OPERATION EMERGENCY
       ASSIGN      4+,1                  *FOR TOMORROW
       LINK        EMRGC,4               *PUT ON EMERGENCY CHAIN
*   THESE ARE SOON ENOUGH
 CLOS2 SAVEVALUE   CHECK+,3,H            *ADVANCE DAY FRIDAY TO MONDAY
       SAVEVALUE   CHKDR,1,H             *START AGAIN WITH FIRST DOCTOR
       ASSIGN      15,1                  *THIS DOCTOR'S DAY OF THE WEEK
       TRANSFER    ,DAYKO                *GO SEE IF THE DAY IS OK
 GTDAY ASSIGN      4,XH$CHECK            *SURGERY DATE TO P4
       ASSIGN      13,P3                 *PRESENT DAY TO P13
       ASSIGN      13+,P9                *P13=TIME OF DISCHARGE NOW
       TEST L      P4,P13,DSPOS          *DISPOSE IF SURG TIME SET BEYOND DISCHARG
       ASSIGN      6,0                   *ENSURE NO BUMPING
       ASSIGN      15,1,V$SGYDW          *P15=SURGERY DAY OF WEEK
       SAVEVALUE   TMFWK,V$APRWK,H       *SET AS ROW FOR APPROPRIATE WEEK'S PTS
       SAVEVALUE   TMFWK+,1,H            *APPROPRIATE WEEK'S TIME IS 1 ROW LATER
       MSAVEVALUE  V$OFFSL+,XH$TMFWK,P15,P11,MH *ADD SURGERY TIME TO SLATED TIME
       MSAVEVALUE  V$OFFSL+,XH$TMFWK,P15,15,MH *ADD TURNAROUND BEFORE NEXT PT
       LINK        V$SLUSC,5             *PUT ON SLATE USER CHAIN
*
*   NOW THE PATIENT ENTERS A HOSPITAL BED
*
 NOINH ENTER       P1                    *ENTER BEDS FOR SERVICE
       LOGIC R     WAIT                  *CAN ALLOW OTHERS NOW
 SAME  MSAVEVALUE  P1+,P6,2,1,MH         *ADD 1 TO PATIENTS ADMITTED
       MSAVEVALUE  P1+,6,2,1,MH          *ADD 1 TO PATIENTS ADMITTED
       TEST NE     P12,0,NOTRQ           *IF 0, NOT A PT WHO REQUESTED DATE
       MSAVEVALUE  P1+,P6,3,1,MH         *COUNT AS REQUESTING
       MSAVEVALUE  P1+,6,3,1,MH          *COUNT AS REQUESTING
       TEST E      P12,P4,NOTRQ          *IF EQUAL, GOT THE RIGHT DAY
       MSAVEVALUE  P1+,P6,4,1,MH         *COUNT SUCCESSFUL ONES
       MSAVEVALUE  P1+,6,4,1,MH          *COUNT SUCCESSFUL ONES
 NOTRQ ASSIGN      13,P3                 *P13=TIME OF ADMISSION
       ASSIGN      13+,P9                *P13=TIME OF DISCHARGE (ADD LOS)
       QUEUE       V$LOSQ                *ENTER QUEUE FOR LOS
       QUEUE       V$LOSQS               *ENTER QUEUE FOR LOS BY SEX
       ASSIGN      15,0                  *ZERO P15 FOR OPERATION COUNT
       PRIORITY    16                    *PRIORITY LEVEL FOR DISCHARGES
       ASSIGN      14,P1                 *AREA TO DISCHARGE FROM
       LINK        DISCH,13              *PUT ONTO DISCHARGE CHAIN
 DSPOS TERMINATE                         *FOR UNWANTED TRANSACTIONS
 FAILD TRACE                             *FOR FAILURE TO OBTAIN MATCH
       UNTRACE
       TERMINATE
****************************************
*   MEDICINE ADMISSIONS PATH
****************************************
*
*   FOR NOW, DO NOT CAUSE ANY TRANSFERS TO OTHER HOSPITAL SERVICES,
*   HENCE NO OPERATIONS (EMERGENCY OR INHOSPITAL)
*
 ADMM  ENTER       P1                    *ENTER BEDS FOR SERVICE
       MARK        3                     *ADMISSION TODAY...TO P3
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              DEPART     V$WAITQ                    *LEAVE WAITING TIME QUEUE
              TRANSFER   ,SAME                      *GO COMPLETE AS SURGICAL
*****************************************
*     EMERGENCY ADMISSIONS UNIT
*****************************************
       EMERG  SAVEVALUE  EMBED+,1,H                 *ADD 1 TO EMERG BEDS IN USE
              SAVEVALUE  EMARR+,1,H                 *ONE MORE HERE TODAY
              MARK       3                          *ADMISSION TODAY...TO P3
              MSAVEVALUE P1+,P6,2,1,MH              *ADD 1 TO PATIENTS ADMITTED
              MSAVEVALUE P1+,6,2,1,MH               *ADD 1 TO PATIENTS ADMITTED
*     DIFFERENTIATE DAYSHIFT ARRIVALS AND OTHERS (FOR PROCESSING SEQUENCE)
              TRANSFER   .200,,MORNG                *TRANSFER TO ARRIVE IN MORNING
              PRIORITY   6,BUFFER                   *PRIORITY FOR NON-MORNING EMERGENCIES
              GATE LR    WAITE                      *ALLOWED TO PROCEED?
              SAVEVALUE  SHIFT,237,H                *FOR NON-MORNING FUNCTION (OWN BEDS)
              TRANSFER   ,BRING                     *GO BRING THEM IN
       MORNG  PRIORITY   12,BUFFER                  *PRIORITY FOR MORNING EMERGENCIES (6-11)
              GATE LR    WAITE                      *ALLOWED TO PROCEED?
              SAVEVALUE  SHIFT,235,H                *FOR MORNING FUNCTION (OWN BEDS)
              TEST E     P1,1,BRING                 *A MEDICAL PATIENT?
              SAVEVALUE  MEMRN+,1,H                 *YES, COUNT
*     PROCESSING BEGINS AGAIN HERE
       BRING  LOGIC S    WAITE                      *STOP OTHERS NOW
              TEST NE    P1,1,NOEIN                 *SEND EMERG MEDICAL REQUESTS TO PROCESS
*     GENERATE EMERGENCY AND INHOSPITAL OPERATION REQUESTS
              TRANSFER   .FN247,,NOEOP              *SEND PROPORTION WITH NO EMERG OP REQUEST
              ASSIGN     11,1,V$SDIST               *P11=LENGTH OF SURGERY
              SPLIT      1,NOEOP                    *OBTAIN ENTITY TO FOLLOW THIS PATH
              MARK       4                          *SAY PRESENT DAY OPERATION
              LINK       EMRGC,LIFO                 *PUT ON HEAD OF EMERG CHAIN FOR TODAY
       NOEOP  TRANSFER   .FN248,,NOEIN              *SEND THOSE NOT PLACING INHOSPITAL OR REQ
              ASSIGN     11,1,V$SDIST               *P11=LENGTH OF SURGERY
              SPLIT      1,NOEIN                    *OBTAIN ENTITY TO FOLLOW THIS PATH
              TRANSFER   ,INHRQ                     *GO HANDLE INHOSPITAL OR REQUEST
*     NOW TRY TO PLACE IN PROPER BEDS
*     IF IMPROPER, MAY ARRANGE FOR TRANSFER TOMORROW MORNING
       NOEIN  LOGIC R    WAITE                      *ALLOW OTHERS NOW
              QUEUE      V$LOSQ                     *ENTER THE QUEUE FOR LOS
              QUEUE      V$LOSQS                    *ENTER QUEUE FOR LOS BY SEX
              ASSIGN     14,P1                      *P14=BED AREA
              TEST LE    R*14,FN*XH$SHIFT,PUTIN *PUT PT IN IF ANY ROOM THERE
              SAVEVALUE  SHIFT+,1,H                 *NOW READY FOR 'OTHER AREA' CHECK
              ASSIGN     15,3                       *UP TO 3 ALTERNATE AREAS
       ALT    ASSIGN     14,MH$ALTER(P1,P15)        *P14=ALTERNATE BED AREA
              TEST NE    P14,0,NMALT                *IF 0, NO MORE ALTERNATIVES
              TEST LE    R*14,FN*XH$SHIFT,ALTOK *ALTERNATE OK IF ROOM THERE
              LOOP       15,ALT                     *ANOTHER ALTERNATIVE?
              ASSIGN     14,0                       *NO ROOM, STAY IN EMERG
              TRANSFER   ,NMALT                     *WILL NEED TRANSFER
*     TRANSFERS ARE FROM P14 AREA ... 0 IS EMERG
*     THESE PATIENTS ARE PUT IN THE WRONG AREA
       ALTOK  ENTER      P14                        *PUT PATIENT IN ALTERNATE AREA
              SAVEVALUE  EMBED-,1,H                 *REMOVE FROM EMERG BED
              MSAVEVALUE P1+,P6,5,1,MH              *INCREMENT NUMBER IN WRONG AREA
              MSAVEVALUE P1+,6,5,1,MH               *INCREMENT NUMBER IN WRONG AREA
              QUEUE      V$WRONQ                    *COUNT PATIENTS BY WRONG AREA
              TEST NE    P14,2,TOVER                *IN OVERFLOW AREA OR NOT?
              TEST NE    P1,1,MDOFF                 *MEDICALS HANDLED SPECIALLY
              TEST LE    R*14,FN239,CNSTA           *IF MORE SPACE THERE, NO XFER
              TRANSFER   ,NMAL1                     *IF LESS, AN IN-HOSPITAL XFER
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         TOVER TRANSFER   .250,,NMAL1              *25% ATTEMPT TRANSFER TO PROPER AREA
               TRANSFER   ,CNSTA                   *READY TO DISCHARGE
*    MEDICAL PATIENTS IN SURGICAL AREAS GET SPECIAL CHAINS
         MDOFF ASSIGN     13,P3                    *P13=TIME OF ADMISSION
               ASSIGN     13+,P9                   *P13=TIME OF DISCHARGE
               PRIORITY   14                       *IN CASE OF TRANSFER
               ASSIGN     15,0                     *ZERO OPERATION COUNT
               LINK       V$MOFF,13                *INCREASING DISCHARGE ORDER
*    THESE MUST TRANSFER SOON
         NMALT QUEUE      V$WRONQ                  *COUNT PTS STAYING IN EMERG
         NMAL1 ASSIGN     15,0                     *ZERO P15 FOR OPERATION COUNT
               ASSIGN     13,P3                    *P13=TIME OF ADMISSION
               ASSIGN     13+,P9                   *P13=TIME OF DISCHARGE
               PRIORITY   14                       *SET PRIORITY LEVEL FOR TRANSFERS
               LINK       XFERC,FIFO               *PUT ON CHAIN TO TRANSFER ASAP
*    THESE PLACED IN PROPER AREA
         PUTIN ENTER      P14                      *ONE MORE PT IN APPROPRIATE WARD
               SAVEVALUE  EMBED-,1,H               *REMOVE 1 FROM EMERGENCY BEDS
         CNSTA ASSIGN     13,P3                    *P13=TIME OF ADMISSION
               ASSIGN     13+,P9                   *P13=TIME OF DISCHARGE
               ASSIGN     15,0                     *ZERO P15 FOR OPERATION COUNT
               PRIORITY   16                       *PRIORITY LEVEL FOR DISCHARGES
               LINK       DISCH,13                 *PUT ONTO THE DISCHARGE CHAIN
****************************************
*    INHOSPITAL TRANSFERS
****************************************
               GENERATE   1,,,,14,3                *TRANSACTION TO INSTIGATE TRANSFERS DAILY
               UNLINK     XFERC,TRYIN,ALL          *UNLINK ALL TRANSACTIONS TO TRYIN
               MARK       3                        *TODAY'S DATE TO P3
               TEST NE    BV$WKEND,1,WEOK          *WEEKENDS OK (DON'T XFER)
               SAVEVALUE  WEEK,0,H                 *THIS WEEK
               SAVEVALUE  PTFWK,V$APRWK,H          *GIVES ROW FOR PATIENTS
               ASSIGN     1,3                      *EENT BEDS
               ASSIGN     2,MH*V$OFFSL(XH$PTFWK,V$WKDAY) *# OF BEDS NEEDED THERE
               ASSIGN     2-,1                     *ALLOW 1 LESS
               TEST G     V$NOFF,0,DOORT           *DOES EENT GET BEDS?
               UNLINK     MALT3,BACK1,V$NOFF,BACK *SEND LONG-STAY MEDS BACK
         DOORT ASSIGN     1,4                      *DO ORTHOPEDICS
               ASSIGN     2,MH*V$OFFSL(XH$PTFWK,V$WKDAY) *# OF BEDS NEEDED THERE
               TEST G     V$NOFF,0,WEOK            *DOES ORTHO GET BEDS?
               UNLINK     MALT4,BACK1,V$NOFF,BACK *SEND LONG-STAY MEDS BACK
         WEOK  TERMINATE                          *REMOVE INSTIGATOR TRANSACTION
*
         BACK1 TEST E     R1,0,TXFER               *ANY BEDS IN MED AREA?
               LINK       V$MOFF,13                *IF NOT, STAY PUT
*
         TRYIN PRIORITY   14,BUFFER                *RESET PRIORITIES FOR TRANSFER
               TEST E     R*1,0,TXFER              *TRANSFER PT IF ANY ROOM THERE
               LINK       XFERC,LIFO               *IF NOT, BACK ON XFER CHAIN
*    THESE GET INTO RIGHT BED NOW
         TXFER ENTER      P1                       *ONE MORE PATIENT THERE
               TEST E     P14,0,NEMG               *UNLESS P14=0, NOT FROM EMERG
               SAVEVALUE  EMBED-,1,H               *REMOVE 1 FROM EMERG BEDS
               TRANSFER   ,TODIS                   *PROCEED TO ARRANGE DISCHARGE
         NEMG  LEAVE      P14                      *OUT OF ALTERNATE AREA'S BED
               MSAVEVALUE P1+,P6,6,1,MH            *ADD 1 TO NUMBER CORRECTED
               MSAVEVALUE P1+,6,6,1,MH             *ADD 1 TO NUMBER CORRECTED
         TODIS ASSIGN     13,P3                    *P13=TIME OF ADMISSION
               ASSIGN     13+,P9                   *P13=TIME OF DISCHARGE
               DEPART     V$WRONQ                  *COUNT PATIENTS FROM WRONG AREA
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        PRIORITY   16                         *PRIORITY LEVEL FOR DISCHARGES
        ASSIGN     14,P1                      *AREA TO DISCHARGE FROM
        LINK       DISCH,13                   *PUT ONTO THE DISCHARGE CHAIN
*****************************************
*   TRANSACTION TO INSTIGATE DISCHARGES
*****************************************
        GENERATE   1,,,,16,13                 *TRANSACTION PER DAY TO INSTIGATE DISCH
        MARK       13                         *TODAY'S DATE IN P13
        UNLINK     DISCH,LEAVE,ALL,13         *ALL PTS TO BE DISCHARGED TODAY TO LEAVE
        UNLINK     XFERC,LEAVP,ALL,13         *INCLUDE THOSE WAITING FOR XFER
        UNLINK     MALT3,LEAVP,ALL,13         *MEDICAL PATIENTS STILL OFF-SERVICE
        UNLINK     MALT4,LEAVP,ALL,13         *MEDICAL PATIENTS STILL OFF-SERVICE
        TERMINATE                             *REMOVE INSTIGATOR FROM MODEL
LEAVP   PRIORITY   16,BUFFER                  *MUST RAISE PRIORITY FOR THESE
LEAVE   DEPART     V$LOSQ                     *LEAVE THE QUEUE FOR LOS
        DEPART     V$LOSQS                    *LEAVE THE QUEUE FOR LOS BY SEX
        TEST NE    P14,P1,NONEM               *PATIENT IN RIGHT AREA?
        DEPART     V$WRONQ                    *NO, COUNT PATIENTS FROM WRONG AREA
        TEST E     P14,0,NONEM                *STILL IN EMERG BED IF 0
        SAVEVALUE  EMBED-,1,H                 *REMOVE FROM THERE
        TRANSFER   ,ONOUT                     *SEND ON OUT
NONEM   LEAVE      P14                        *REMOVE ONE PT FROM THAT BED POOL
ONOUT   TEST E     P14,1,BYE                  *A MEDICAL AREA DISCHARGE?
        SAVEVALUE  MADIS+,1,H                 *YES, COUNT
BYE     TERMINATE                             *REMOVE PATIENT FROM MODEL
*****************************************
*   OPERATING ROOM DATA
*****************************************
*
*   SINCE THE SIMULATION OF THE SURGICAL THEATRES WOULD INVOLVE A MORE MICRO
*   LEVEL OF TIMING THAN 1 DAY, IT IS NOT BEING DONE IN DETAIL.
*   IT IS HOPED THAT DOCTOR'S TIME ESTIMATES WOULD IMPROVE, AS WOULD THE
*   BOOKER'S EXPERIENCE. HENCE ACTUAL (NOT ESTIMATED) TIME DISTRIBUTIONS
*   ARE USED.
*   MEAN TURNAROUND IS CONSIDERED TO BE 15 MINUTES. IF 4 OPERATIONS WERE DONE,
*   FOR EXAMPLE, THERE WERE 3 TURNAROUNDS - ONE OVER LUNCH, SO 2*15 IS ADDED.
*   THIS IS DONE FOR EACH OPERATING ROOM REPRESENTED.
*
        GENERATE   1,,,,2,5                   *SINGLE TRANSACTION FOR OR RECORDS
        ASSIGN     1,4                        *P1=HOSPITAL SERVICE, 4 IS HIGHEST
        MARK       4                          *TODAY'S DATE IN P4
        SAVEVALUE  WEEK,0,H                   *DOING THIS WEEK'S OPERATIONS
        TEST G     P4,XH$PWEEK,NOWEM          *ON WEEKEND, ONLY EMERGENCIES
ROOM    TEST NE    P1,2,NOWEM                 *DON'T DO SERVICE 2
        ASSIGN     5,V$SRVOP                  *P5=SERVICE'S OP TIME SAVEVALUE
        SAVEVALUE  P5,0,H                     *SET IT TO 0
        ASSIGN     5+,1                       *P5=SERVICE'S NUMBER OP SAVEVALUE
        SAVEVALUE  P5,0,H                     *SET IT TO 0
        UNLINK     V$SLUSC,PRFRM,ALL,4,,ZROSL *FOR THIS DATE/SERVICE, REMOVE
        LOOP       1,ROOM                     *DECREMENT SERVICE AND GO TO ROOM
        TRANSFER   ,NOWEM                     *AFTER THE LAST SERVICE
ZROSL   ASSIGN     2,V$HITBL                  *P2=NUMBER OF HIGHEST TABLE OF SERVICE
        TABULATE   P2                         *RECORD 0 TIME
        ASSIGN     2-,1                       *SUBTRACT 1
        TABULATE   P2                         *RECORD 0 PATIENTS
        LOOP       1,ROOM                     *DECREMENT SERVICE AND GO TO ROOM
NOWEM   SAVEVALUE  EMGTM,0,H                  *SET EMERG OP TIME TO 0
        SAVEVALUE  EMGNO,0,H                  *SET EMERG OPERATED NUMBER TO 0
        UNLINK     EMRGC,AFTER,ALL,4,,ZROEM   *ALL TODAY'S EMERG OPN OFF THAT CHAIN
        TERMINATE                             *REMOVE INSTIGATING TRANSACTION
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ZROEM TABULATE   EMTBN                   *RECORD 0 PATIENTS
      TABULATE   EMTBT                   *RECORD 0 TIME
      TERMINATE                          *REMOVE INSTIGATING TRANSACTION
*
*   HERE THE PATIENT'S OPERATION IS ADDED INTO RECORDS
*
PRFRM PRIORITY   2,BUFFER                *RESET PRIORITY
      ASSIGN     13,V$SRVOP              *P13=SAVEVALUE OF SERVICE OP TIME
      SAVEVALUE  P13+,P11,H              *ADD LENGTH OF THIS SURGERY
      ASSIGN     13+,1                   *P13=SAVEVALUE OF SERVICE'S OPERATED NO. .
      SAVEVALUE  P13+,1,H                *ADD 1 SURGERY
      TEST G     XH*13,FN242,NOTRN       *IF 'LE' 2+ PER OR, NO TURNAROUND TIME
      ASSIGN     13-,1                   *BACK TO TIME SAVEVALUE
      SAVEVALUE  P13+,15,H               *ADD 15 MINUTES TURNAROUND
NOTRN TEST E     W$PRFRM,0,NOMR          *SOME MORE UNLESS NO MORE UNLINKED
      ASSIGN     14,P1                   *REAL SERVICE OF THIS PATIENT
      ASSIGN     1,4                     *HIGHEST SERVICE
TAB   ASSIGN     13,V$HITBL              *P13=NUMBER OF HIGHEST TABLE OF SERVICE
      TEST NE    P1,2,DNTAB              *DON'T DO SERVICE 2
      TEST NE    XH*V$SRVOP,0,SKIP       *DON'T RETABULATE IF 0
      TABULATE   P13                     *TABULATE TIME FOR THIS SERVICE
      ASSIGN     13-,1                   *SUBTRACT 1
      TABULATE   P13                     *TABULATE NUMBERS FOR THIS SERVICE
SKIP  LOOP       1,TAB                   *SUBTRACT 1 FROM SERVICE, GO TO TAB
DNTAB ASSIGN     1,P14                   *RESTORE REAL SERVICE
AFTER PRIORITY   2,BUFFER                *RESET PRIORITY
      SAVEVALUE  EMGTM+,P11,H            *ADD LENGTH OF SURGERY
      SAVEVALUE  EMGNO+,1,H              *ADD 1 SURGERY
      TEST E     W$AFTER,0,NOMR          *SOME MORE UNLESS NO MORE UNLINKED EMG.
      TABULATE   EMTBN                   *TABULATE TODAY'S EMERGENGY OP NUMBER
      TABULATE   EMTBT                   *TABULATE TODAY'S EMERGENGY OP TIME
NOMR  TERMINATE
***************************************
*   PRINTER TRANSACTION
***************************************
      GENERATE   91,,91,,2,1
      PRINT      ,,C,N                   *CLOCK
      PRINT      ,,U,N                   *USER CHAINS
      PRINT      ,,S,N                   *STORAGES
      PRINT      ,,Q,N                   *QUEUES
      PRINT      38,38,T,N               *NOBED TABLE
      PRINT      1,4,MH,N                *SERVICE MATRICES
      PRINT      40,41,XH,N              *MEDICAL AREA COUNTERS
      TERMINATE
***************************************
*   TIMER TRANSACTION
***************************************
      GENERATE   1                       *ONE PER DAY, LAST THING
      TABULATE   EMGDU                   *TODAY'S EMERG AND D.U.PATIENTS
      SAVEVALUE  EMARR,0,H               *RESET FOR TOMORROW
      TABULATE   NOBED                   *TODAY'S 'NO BED' CANCELLATIONS
      SAVEVALUE  NOBD,0,H                *RESET FOR TOMORROW
      TERMINATE  1                       *REMOVE AND COUNT
*
      START      91,NP
      RESET
      START      91,NP
      RESET
      SAVE                               *SAVE 1/2 YEAR MODEL
      START      91,NP
```

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          RESET
          START      91,NP
          RESET
          SAVE       2C                        *SAVE 1 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       3C                        *SAVE 1 1/2 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       4C                        *SAVE 2 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       5C                        *2 1/2 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       6C                        *3 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       7C                        *3 1/2 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       8C                        *4 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
          RESET
          SAVE       9C                        *4 1/2 YEAR MODEL
          START      91,NP
          RESET
          START      91,NP
    *
          RESET                               *END OF 5 YEAR RUN
          GENERATE   1,,,1,25                  *TRANSACTION TO CLEAR SAVEVALUES
          MSAVEVALUE 1-4,1-6,1-6,0,MH          *ZERO ACCUMULATED NUMBERS FOR PTS
          SAVEVALUE  CANCL,0,H                 *ZERO CANCELLATION COUNTER
          SAVEVALUE  40-41,0,H                 *ZERO MEDICAL AREA COUNTERS
          TERMINATE
          SAVE       10C                       *SAVE ALSO 5 YEAR MODEL
    *
          END
```