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DEVELOPMENTS IN PLANNING MODELS FOR HEALTH CARE POLICY ANALYSIS IN THE U.K.

M. CLARKE AND A.G. WILSON

School of Geography
University of Leeds
Leeds LS2 9JT

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1. INTRODUCTION

Problems of spatial organization and associated planning issues in the National Health Service are currently attracting a good deal of attention from a variety of interested parties. However, until fairly recently, little prominence has been given to these problems either by health care professionals or academics. This has now all changed. Developments such as the RAWP formula for resource allocation (DHSS 1976) and the publication of the Black Report (Townsend and Davison 1982) have emphasised, first, the gross spatial inequalities in the provision and uptake of medical care in the U.K., and secondly, the need for careful and detailed planning of resource allocations across space. This was further confirmed by the publication of the first set of Performance Indicators for the NHS by the DHSS in 1983 which showed marked variations between health authorities on a number of fronts, such as cost per case, lengths of stay, occupancy rates and so on.

In the face of public expenditure cuts in general, many health authorities have faced real reductions in their resources : it becomes ever more important to plan effectively. Gone are the days when the Operation plan could be rolled forward every year and the Strategic plan every few years. Planning could once restrict itself to the design and implementation of new projects out of growth and the rest could be based on the historical allocation. Now there are major decisions to be made on almost every front - decisions having major consequences for levels of care in an authority.

What we attempt to describe in this paper is how computer-based models can help planners and decision makers in their analysis of policy, particularly those related to spatial issues such as the location of facilities and access to them. In the next section we examine some of the causes of the problems now faced by health authorities. This is followed in section 3 by an overview of some of the relevant models that have been developed in recent years. In section 4, we present two different types of planning model developed in Leeds. The first (subsection 4.1) is a district model based on micro-simulations methods; the second (subsection 4.2) is a regional interactive strategic planning model. We give examples of their use in both cases.

2. PROBLEMS OF PLANNING AND LOCATIONAL ANALYSIS IN HEALTH CARE SYSTEMS

In this section we examine the nature and scope of a selected range of planning problems in health care systems, focussing in particular on spatial issues. These are discussed in relation to the British National Health Service (NHS) but broadly speaking there will be equivalent problems in other countries. Emphasis is concentrated on acute or hospital-based health care since that is where the majority of resources are allocated. Other sectors are important, of course. In the longer run, similar methods can be applied to them; and this will facilitate exploring the interaction between hospital care and, for example, community provision.

The NHS, established in 1948, is centrally funded out of general taxation. Effectively, local health authorities have no powers to generate their own resources; their allocations come in annual revenue and capital budgets from Regional Health Authorities. Regions are allocated funds from the DHSS according to a formula known as RAWP - Resource Allocation Working Party - which we describe in more detail below.

The first form of administrative spatial organization of the NHS, which lasted from inception until 1974, consisted of 13 Regional Hospital Boards (RHBs) and individual hospitals were administered by hospital management committees (HMCs). RHBs saw their main planning responsibility as deciding where new hospitals should be built and responsibility was then passed to a new HMC. Little effective coordination of service provision emerged from all this (Bevan and Spencer, 1984) although there was considerable concern as to what constituted the 'optimum size' (in terms of numbers of beds) of hospitals. The Bonham-Carter report (MoH, 1969) made a number of suggestions as to the norms of service provision - such as the number of consultants in a given specialty per 100,000 population - but these were never fully implemented. And in any case, as we will see, such simple norms need to be carefully treated because of overlapping catchment populations. In 1974, there was a reorganization - a rather hasty one compared with the more carefully considered reorganization of local government at around the same time. The NHS now consisted of three tiers - Regional, Area and District. The first two formed Health Authorities and the third was a basic management unit. For the first time there was a statutory duty to produce Strategic plans for the Secretary of State's approval. This implied that planning at least had to be seen to be taken seriously. The Planning system became oriented towards service groups, such as the elderly, children, mentally handicapped, acute services and so on. Although this was seen as an improvement over what previously existed there were considerable reservations about its structure particularly the overlap between these groups. For example 50% of acute beds are occupied by persons over the age of 65. The establishment of this system also coincided with the first phase of reduced growth in NHS funding, which implied that for the new developments in one area had to be paid for by cutbacks in another.

In 1982 there was a further reorganization : the Area tier was abolished and the Districts were made the focus of local planning and became the second tier of Health Authorities below the region. There are now 14 regions in England, and 192 districts with an average population of around 230,000.

A major problem in the planning and organization of the health care system is the diversity in the range of services provided. In relation to spatial scale, these typically can be divided into national specialties (e.g. heart transplantation), regional specialties (e.g. neurosurgery, plastic surgery), sub-regional specialties (e.g. urology, thoracic surgery) and the specialties which would normally be found in every district (general medicine, surgery, gynaecology, etc.). Although this hierarchical system implies that every facility cannot be provided in every location we can note that the actual spatial distribution is biased towards the main metropolitan regions, London in particular. In addition, the large teaching hospitals in the main provincial cities tend to be well endowed with specialised facilities; and rural areas and smaller towns less so. This may indeed be a sensible way to organize the service but to determine this we need to compare relative accessibility to services on a systematic basis. This turns out to be, not surprisingly, an example of the equity-efficiency trade off which is common in spatial policy analysis. This is further compounded by the observed relationship between the supply of services and the concomitant demand for it. Mayhew (1979) showed, that in London at least, hospitalization rates were positively correlated with service supply and accessibility, confirming Feldstein's (1967) findings in a more general context. The implications of this relationship are profound. It suggests that in areas of the country where provision of services is high (London and the major cities) more people receive treatment than the national average and in other areas, people who would be treated if they lived near to a hospital are not so treated. Given the increasing tendency towards the centralisation of services (particularly acute services) there is a potential danger of even greater differentials in treatment rates.

It was partly in relation to the problem of the inequity in the allocation of resources over space that the Resource Allocation Working Party was set up in 1975. Its remit was to review the arrangements for distributing NHS capital and revenue in an efficient and equitable way in relation to relative need. The report from the group DHSS (1976) has subsequently attracted much attention, a good deal of criticism and generated a new sub-discipline within the health care system devoted both to understanding how it works and how to take best advantage of it. The basic idea behind the RAWP method as it became known, was the calculation of resource targets based on the residential population of regional authorities and the expenditure the region would incur if it provided services at national average rates. The actual calculation of these targets is complex but in principle they take account of differences in the population structure of regions and variations in the morbidity rates as measured through variations in Standardised mortality ratios (SMRs). The idea is that existing revenues can then be compared with these targets and gradually actual revenues will, over time, move towards the targets. In general the London regions would face substantial reductions in their revenue allocations while most of the other regions would have targets somewhat higher than their existing allocations. The planning problems that now face the London regions are considerable because progress has been made in resource allocation and they imply the closure of large and prestigous hospitals, notably in central London. How quickly regions will move towards their target remains to be seen, but clearly instantaneous adjustment would not be feasible from either a political or administrative point of view.

Allocations from Region to District take a variety of forms, most common of which is a modified local version of RAWP. Because there is often much variation in the range of services offered by individual districts (some will obviously contain regional and sub-regional specialties), authorities are compensated for treating patients from other districts and vice versa. This leads on to the important concept of catchment populations, which can be considered as the actual population that a district serves, for a given specialty or all specialties. They are calculated in relation to cross-boundary flows. We shall return to the issue of catchment populations at subsequent stages of this paper and we also present a detailed algebraic exposition of the technical problems associated with calculating catchment populations in Appendix 1.

Given this background, what are the typical types of problems being faced by planners both at the Regional and District level? We offer the following list as being representative of some of the main problems:

(a) Changing patterns of demand

It is important to link the planning of health service supply to the changing social geography of regions and districts. Changing residential patterns - e.g. outmigration and decentralization - together with changing demographic structures, especially the growth of the elderly population, have different impacts on different types of regions and districts. For example, some RHAs, such as Oxford and East Anglia have experienced significant population growth in recent times, this largely being at the expense of the London regions. However, there tends to be a notable lag in the time it takes before the appropriate resource adjustments are made. Clearly this is an area where detailed models of demographic and social change could provide forecasts of likely future population structures.

(b) Hospital planning - new developments

Although the development of new district general hospitals on green field sites tends to be the exception rather than the rule these days there are still a sufficient number of new health care facility developments to warrant interest. These may include the expansion of facilities on a particular site or the establishment of new types of units, such as those specifically designed for the elderly and mentally infirm (e.g. ESMI units). In addition the planning of new specialties, particularly at the regional scale, often involves important location decisions. In all these cases location models have potentially a good deal to offer the health care planner, and we shall present examples of these in the next section.

(c) Hospital planning - rationalisation

More typically health authorities are faced with rationalising existing facilities and this may of course involve closing some hospitals completely. This too needs careful planning and there will usually be a wide range of options that should be examined. In many cases there will also be a need to look at the impacts on adjoining districts, as closure or reduction in the level of supply might imply the transfer of demand to other care centres. For this, the regional planning model we outline in section 4.2 may be particularly useful.

(d) New technological developments

As technology advances new types of treatment and diagnostic facilities become available, but at a cost. On average the rate of increase in the cost of new technology is considerably above the rate of inflation. How can these new developments be funded and where should they be located?

(e) Alternative forms of care

There is a growing tendency to shift certain types of care from being hospital-based to being community-based. This is particularly the case with mentally ill and handicapped services and also with geriatric care. In addition the development of day care hospitals or wards as an alternative to traditional in-patient treatment is an important policy issue, notably in relation to the surgical specialties. These all need careful planning in terms of costs, organization and location, and the impact upon the various client groups also needs to be assessed.

These, then, form some of the main policy issues being faced at the moment. We can now turn our attention to an assessment of some methods that have been developed to help shed light on these issues, before presenting the two models we have developed, in section 4.

3. THE APPLICATION OF LOCATION-BASED MODELS IN HEALTH CARE PLANNING : A SELECTIVE REVIEW

3.1 Introduction

In this section we briefly discuss a number of different types of modelling approaches that have been developed to examine health care planning issues, particularly those with a spatial component. Until fairly recently, the main interests of medical geographers have been outside this model-based approach and its contribution to planning; they focussed more on problems of epidemiology and spatial variations in morbidity and mortality. The main academic interest in model-based analysis developed originally in disciplines such as operations research and health economics. This is now changing as geographers begin to appreciate the potential of methods derived within their own discipline to spatial aspects of health care policy analysis. In this section we outline some of these by looking at a variety of allocation problems and the methods developed for tackling them.

3.2 The spatial allocation of facilities

The location of health care facilities is an obvious geographical area of interest. The group of methods that come under the location-allocation umbrella were originally developed for management science problems, such as the warehouse location travelling salesman problems, but have subsequently seen application in geography. Hodgart (1978) and Beaumont (1981) both provide good reviews of this family of models. Broadly speaking they are concerned with finding the optimal location of certain types of facilities and the allocation of demand to that site. They inevitably assume that demand is allocated to the nearest supply point. This is clearly a restrictive assumption and has been relaxed by the development of non-linear programming methods based around entropy maximisation techniques (see Wilson, *et al.*, 1981). Examples of their use in health care planning are rather limited although Dokmeci (1979) and Riley (1981) provide useful tentative attempts to incorporate some of these ideas. One of the difficulties that has to be faced in any optimisation problem is the specification of an objective function. In location-allocation this is usually the minimization of total weighted travel cost. In health care planning the objectives are usually more complex and multi-dimensional than this (although good examples of the use of location-allocation models is provided by the ESMI location problem, see Beaumont and Sixsmith, 1984). One of the principal arguments advanced in favour of the use of optimisation models in general is that of the combinatorial nature of most location problems. That is, for most situations the possible range of options is so enormous that only computer-based search procedures could examine all the combinations of possibilities. We believe that in health care, at least, this is generally an overstatement of the problem. For most planning decisions relating to the opening or closure of facilities the range of possibilities is effectively rather small due to the large number of constraints that exist - such as possible available sites, making use of existing sites, and so on. Rather than employing sophisticated optimisation methods planners may be better advised to employ methods that allow them to generate their own solutions to problems and examine in more detail the consequences of these decisions. If this is done in an interactive computing environment along the lines suggested in section 4.2 so much the better.

Of course it is possible to find exceptions to this general argument - the location of emergency facilities, such as ambulance stations, is a good example, where optimisation methods may provide a useful methodology.

3.3 Resource to specialties

During the late 1970s at the International Institute for Applied Systems Analysis in Vienna a special Research Task area devoted to examining health care resource allocation problems was established. A significant product of this group was a family of models developed for allocating resources to specialties over space. These models were given acronyms such as RAMOS (Resource Allocation Model Over Space) and were in the main mathematical programming models designed for strategic allocation problems. Some were developed for use at the national level, for allocation to regions (Gibbs, 1978), Aspden, Rusnak and Mayhew, 1981) and others for allocation at the Regional level (between districts) - Aspden (1980). More recently these models have been extended to incorporate specific objectives such as maximising, efficiency and accessibility subject to certain bounds and applications of these models to resource allocation in Massachusetts can be found in Mayhew and Leonardi (1984) and for a more general overview see Mayhew and Leonardi (1982).

3.4 Allocation of patients to hospitals

In Britain, at least, general practitioners are in principle free to refer patients to a consultant of their choice. This may involve the patient being treated in a health district other than the one he or she lives in. To acknowledge that these cross-boundary flows have important resource consequences for health districts account is made of them in the resource allocation calculations. An important planning problem therefore arises when a new facility is to be developed or an existing one to be re-located or closed. What are the impacts on patient flows, and hence resource allocations?

It is in response to these equations that the family of spatial interaction models (Wilson, 1970) has been applied to modelling patient flows. These models have been widely applied in a range of areas, such as transport modelling, retail planning and problems or residential location but their use in patient flow analysis is comparatively recent (Mayhew, 1979 is probably the first example). However, there is now a great deal of interest in the application of these models in strategic planning. This is probably a response to the development at the DHSS of its own 'gravity' model (Mayhew and Tackett, 1980), the use of which was promoted at the Regional level. Indeed, the first of the new round of Regional Strategic Plans published by North East Thames RHA bases much of its analysis around results derived from its own spatial interaction model (NETRHA, 1984). In addition the model we describe for Regional Planning in section 4.2 is underpinned by a spatial interaction model of patient flows. One notable spin-off from these models is that they allow catchment populations to be calculated, and as this is the basis of resource allocation it is of considerable use in forward planning.

However, it is perhaps worth emphasising that as with any model-based approach, mis-use of spatial interaction models can make a mockery of their contribution to planning. Spatial interaction models are underpinned by a set of assumptions and constraints, each of which may be specific to a given set of conditions that pertain to a particular application. It is important to be aware of what these are and how they may influence the results obtained. It is sensible to ensure that a good deal of sensitivity analysis is employed to test the robustness of the results obtained to the assumptions contained within these models.

3.5 Allocation of patients to specialties and care types

A patient with a given condition could often be treated in a number of different ways. This is particularly true for the elderly where they tend to have a number of different attributes (frailty, senility, incontinence, etc.) which have to be taken into account. For example a frail elderly person could be cared for at home, with the provision of a home help, meals-on-wheels, a visiting nurse, etc.; in residential care, where all these services are provided at one location; or in hospital if one of the conditions is particularly severe. Typically the demand for each form of care will exceed available supply and some priority scheme is necessary. To attempt to examine these problems a 'balance of care' model (McDonald *et al.*, 1974) has been developed by the DHSS and is now finding application in planning, e.g. Mooney (1978), Boldy and (1980). This model is a linear programming package aimed at maximising the effectiveness of care subject to the usual resource constraints.

An alternative approach is based on micro-simulation methods, in conjunction with linear programming, to allocate individual patients to particular care packages (Clarke and Prentice, 1982).

3.6 Concluding comments

This review has been necessarily brief and subjective. What does appear, fairly strikingly, is that what characterises the present situation in terms of model development is that it is multi-disciplinary, in that there are a variety of contributions from different areas. What,it could be argued,is needed is a truly inter-disciplinary approach whereby different techiques and ideas are combined. Geographers with their tradition in this type of synthesis, are strongly placed to push this idea forward.

4. SOME NEW METHODS FOR HEALTH CARE PLANNING

4.1 A district simulation model

In this section we outline a planning model that has been developed for use at the district scale. The model described has been implemented for a district health authority in the North of England and is currently being used in the planning of a new DGH. Space restricts us to presenting only the main features of the model and we refer the reader to Clarke and Spowage (1982, 1985) for a more detailed description of the model and its use.

The model is constructed using micro-simulation methods. These involve the specification of lists of individuals and households characterised by a relevant set of attributes, such as age, sex, marital status, race, location, employment and so on. The reasons for adopting this form of representation relate to the efficient storage of a heterogenous population on a computer and to issues involving the handling of complex interdependencies between individual attributes. The technical details of this can be found in Clarke, Keys and Williams (1981) and Clarke (1985). Suffice to say, at this stage, that for the examination of detailed planning issues at the district level it is important to consider a wide range of attributes relating to both the supply and demand components of a health care system. In addition to represent alternative policies in a district model account must be taken of the complexity and interdependencies found at this level. We believe that the micro-simulation approach is the most suitable method for handling all these factors at this scale of resolution.

The model consists of five main components which are shown in Figure 4.1.

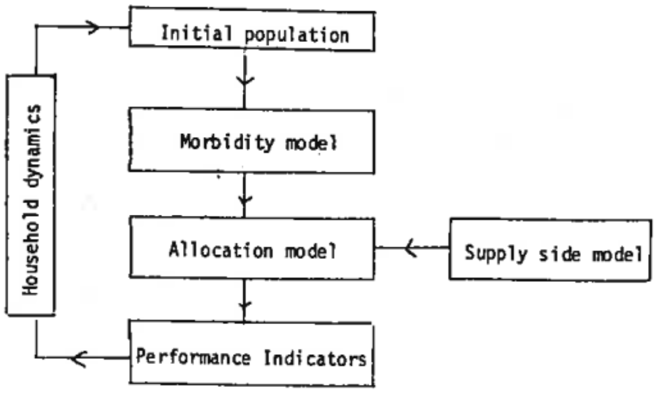

FIGURE 4.1. STRUCTURE OF DISTRICT MODEL

We now describe each of these in turn.

For any micro-simulation model it is necessary to start with an initial population of households and/or individuals specified at the micro-level. This may be obtained from a survey but this is not always possible and resort to synthetic sampling methods is necessary. This involves taking known aggregate distributions of attributes from sources such as the census and so on and forming a set of joint probability distributions using bi-proportional fitting methods (see Clarke, 1985). From these joint distributions it is possible to use Monte Carlo sampling procedures to generate lists of individuals and households whose attributes in aggregate will closely correspond with those known distributions.

Given this initial population we shall wish to update its characteristics for each year of the simulation period. Once again we employ Monte Carlo sampling in conjunction with list processing to achieve this. Various conditional probabilities that relate to demographic transitions are obtained (for example the probability of giving birth, by age, marital status and race). For each individual in the sample list we test for possible transitions for all eligible events. If a transition is deemed to have occurred then the appropriate attribute is changed and any other changes accounted for (e.g. if one spouse dies then the marital status of the remaining spouse changes). In this way the changes in the demographic structure of the population are picked up at quite a fine level of detail.

The morbidity model is likewise specified at a high level of resolution.

Morbidity is a very difficult concept to define, measure and model. What we have attempted to do is adopt a first principles approach to the problem and make the best use of the data that is available. The structure of the model is represented, in simplified form, in Figure 4.2. An attempt is made to model the variety of forms by which an individual becomes a potential in-patient. This involves modelling morbidity around both the G.P. referral process and the accident and emergency system. Data on the G.P. system is poor, the only nationally collected data being contained in the reports of two surveys undertaken in the early 1970s (DHSS/OPCS 1978, 1979). This data contains information on the probability of an individual visiting a G.P., having a certain condition diagnosed and being referred along one of the channels shown in Figure 4.2. This data was modified for the health district using Hospital Activity Analysis (HAA) data by balancing factor methods so that the predicted number of referrals matched observed referrals in the base year. Thus we can sample for each individual in our population to determine whether they visit a G.P. in a given year (or more than once) and if so determine the outcome, in terms of condition diagnosed and the outcome (referral, non-referral, etc.). These outcomes form additional attributes for an individual, where relevant. Added to this is a test for accident and emergency admission, again along with a condition and outcome. This information was collated from a detailed analysis of casualty department registers in the health authority. The full morbidity model is detailed in Figure 4.3. Additional components of demand such as the previous year's waiting list and in-flows into the district are also accounted for.

The next stage is to transfer demand by condition into demand for care by specialty. This requires HAA data to provide the appropriate mapping, in this case the probability of admission to a specialty given condition, age and sex.

The result of this procedure is to produce a sub-population of individuals with appropriate attributes that forms the demand for in-patient care in a given year. The next step in the model is to allocate this demand to available supply. This can be achieved in a number of ways. The one we describe here is based on 'current practice', although it can be easily modified to account for changes in policy and so on. We take HAA data on admissions and calculate the probability of an individual with a given set of attributes (age, sex, condition, location) being allocated to one of the hospitals in the district. The allocation model begins with allocating all priority cases to a given hospital - these include direct admissions, accident and emergency cases and district in-flows (as the information on the latter is a measure of patients treated). There then follows the allocation of non-emergency cases, this is achieved using the list processing method described earlier. When all available supply has been allocated or all patients admitted the model ends. Unsatisfied demand is considered to form the next time period's waiting list. Figure 4.4 diagrammatically summarises the allocation sub-model.

The supply side is represented in terms of bed-days available by specialty and hospital together with an appropriate treatment cost per day. In the allocation model patients on admission are assigned a length of stay, based on age and condition. This length of stay is deducted from the available supply and also is used to calculate the cost per case, which becomes another individual attribute. The cost model is not described here but is discussed in detail in Forte and Wilson (1985).

The model is run for each year successively for, say, a ten-year time period. At the end of each year, a range of information is output providing a detailed breakdown on system performance and at the end of the whole simulation period a time series of performance indicators is produced in summary form. The whole computer package runs in an interactive mode with the user being asked to input details on policy options and to request what performance indicators are required. A taste of the range of output is presented in Tables 4.1-4. ; for further details see Clarke and Spowage (1985). As mentioned above the model has been successfully used for policy analysis in a district health authority and further dissemination is under way.

4.2 A regional model

We now shift to the regional scale of analysis. A typical Regional Health Authority may be subdivided into 10 or more districts - in Yorkshire there are as many as 17 - and a perspective is now demanded which provides an aggregate view of each of these. This picture should facilitate the development of policies to allocate resources to districts, to monitor and improve performance and the planning of sub-regional and regional specialties. What is needed, therefore, is a portrait for each district in the region of morbidity, facilities available and the patterns of use. The last of these, essentially patient flows, will include inter-district flows. Out of this information, a set of performance indicators can be generated. Given this kind of information, a Regional Authority and its officers potentially have the basis for making effective policy decisions. This planning and policy-making function can be much facilitated by the availability of a capability for interactive planning : to be able to compute and compare the impacts of a range of alternatives. In order to provide the relevant information, a set of models is needed both to generate missing information for the current situation and to enable predictions to be made of the consequences of changing demand patterns or alternative policies.

In the rest of this section we sketch in turn the elements of a system of the type described under the following sub-headings: system description; models; performance indicators; an interactive planning framework and a commentary and appraisal system.

System description

The main variables which illustrate the characteristics of a regional multi-district health care system are :

Demand :

P_i^{as}	: population in district i by age (a) and sex (s)
R_i^{kas}	: morbidity rates for the (i,a,s) - population generating cases for specialty, k.

Supply :

A^*_j	: total beds in district j.
C^*_j	: total budget (or expenditure) in (or for) district j.
U^*_j	: average occupancy rate at j.
H^*_j	: average length of stay at j.
X^*_j	: total number of cases at j.
A^k_j	: number of beds in specialty k at j.
C^k_j	: budget (or expenditure) for specialty k at j.
U^k_j	: occupancy rate for specialty k at j.
H^k_j	: average length of stay for specialty k at j.
X^k_j	: number of cases in specialty k at j.

Use :

N^{*}_{ij} : total flow of patients from residences in i to hospitals in j.

N^{k}_{ij} : flow of patients from i to j by specialty k.

c_{ij} : the 'cost' of travel from i to j.

Resource inputs on the supply side are measured here in money terms by budget or expenditure. It may also be appropriate to specify these in more detail : medical staffing, nursing staffing, pharmacy, etc. However, the above broad specification will suffice for illustrative purposes.

Models

There are four subsystems implicit in the system description for which models need to be built. These relate to (i) demography and morbidity (P_i^{as}, R_i^{kas}); (ii) flows, N^{*}_{ij} and N^{k}_{ij} in relation to c_{ij} and demand and supply variables; (iii) specialty costs, C_j^k, since these are typically not available from data; (iv) catchment populations. We outline these models briefly in turn.

Demography and morbidity

We have already discussed micro-simulation models in relation to the district scale and one possibility here is to use aggregates of those models. Otherwise, standard models should be used (cf. Rees and Wilson, 1977). We need to finish up with an estimate of demand by specialty :

$$E_i^k = \sum_{as} P_i^{as} R_i^{kas} \tag{1}$$

Flows

We concentrate here on N_{ij}^k - flows by specialty. For a given period, we need to match demand, E_i^k, to the capacity to treat cases, which we identify with X_j^k. We would then typically use either a production-constrained or a doubly-constrained spatial interaction model :

$$N_{ij}^k = A_i^k L_i^k X_j^k e^{-\beta^k c_{ij}} \tag{2}$$

with

$$A_i^k = 1/\sum_{\ell} X_{\ell}^k e^{-\beta^k c_{i\ell}} \tag{3}$$

to ensure that

$$\sum_j N_{ij}{}^k = E_i{}^k \qquad (4)$$

This model will then provide an estimate of cases treated, say

$$\hat{X}_i{}^k = \sum_j N_{ij}{}^k \qquad (5)$$

and $\hat{X}_i{}^k \,/\, X_i{}^k$ is then itself a useful performance indicator, showing under-use, balance or overcrowding in an obvious way. If it is thought that demand and supply are matched, then a doubly-constrained model should be used :

$$N_{ij}^k = a_i^k \; b_i^k \; E_i^k \; X_i^k \; e^{-\beta^k c_{ij}} \qquad (6)$$

with

$$a_i{}^k = 1/\sum_\ell b_\ell{}^k X_\ell{}^k e^{-\beta^k c_{i\ell}} \qquad (7)$$

$$b_j{}^k = 1/\sum_\ell a_\ell{}^k E_\ell{}^k e^{-\beta^k c_{\ell j}} \qquad (8)$$

which ensure that (4) holds together with

$$\sum_i N_{ij}{}^k = X_j{}^k \qquad (9)$$

If the flow pattern for a region is an odd one which does not fit either of these models (or a modification of them), then it may be better to use the marginal flow model which builds on the existing flows and only allocates by model at the margin. This model is articulated in Clarke and Wilson (1984).

Specialty costs

One of the greatest problems in the development of effective planning procedures in health care is the lack of systematic information on costs of the main functioning units - specialties. Eventually, this situation should improve when the recommendations of the Korner Committee are implemented (DHSS, 1982). Meanwhile, it is necessary to resort to modelling.

There are three main types of approach to modelling specialty costs : regression analysis, cost accounting and balancing factor methods. The task is : given $C_j{}^n$, the costs of resource inputs n to hospital (or district, in this case), j, how can we allocate these to specialties k to obtain either C_j^{nk} or C_j^{*k}? The authors of all methods recognise that there are at least three kinds of costs to be allocated : overheads, 'hotel' costs - per bed day, and treatment costs, per case. Thus C_j^n can be regressed against variables like A_j^k and X_j^k (which were introduced earlier) and the coefficients taken as elements of specialty costs. The cost accounting method involves detailed measurement in particular hospitals. The balancing factor method involves an attempt to make the best use of the latter by showing how to find proportionality factors to apply to specific surveyed costs to force them to sum to C_j^n totals for another district or hospital.

All the methods are reviewed and described in Forte and Wilson (1985). The two main regression models are those of Coverdale, Gibbs and Nurse (1980) and Ashford and Butts (1979). Cost accounting methods are associated with Magee and Osmolski (1978). The balancing factor model is demonstrated in Forte and Wilson (op.cit.).

Catchment populations

Given the flows N_{ij}^k and N_{ij}^*, it is necessary to calculate allocations of P_i^{**}, the total population of i, to j, both for each specialty k and in aggregate. This means it is necessary to calculate P_{ij}^k and P_{ij}^* (and the asterisk in this case does not denote summation) such that

$$\sum_j P_{ij}^k = P_i^{**} \qquad (10)$$

$$\sum_j P_{ij}^* = P_i^{**} \qquad (11)$$

and then

$$Z_j^k = \sum_i P_{ij}^k \qquad (12)$$

and

$$Z_j^* = \sum_i P_{ij}^* \qquad (13)$$

are in an obvious sense catchment populations. As we will see shortly, they are important in the calculation of performance indicators. Unfortunately, the procedure for calculating P_{ij}^k is not the obvious one of a simple scaling up of N_{ij}^k - this leads to inconsistent results. But a model can be specified which is suitable for most situations and it is described in the Appendix.

Performance indicators

There are two fundamentally different types of performance indicators : those relating to the delivery of health care by residential district; and those relating to the efficiency of provision by facility district. In the first case, it is necessary to sum quantities in proportion to N_{ij}^{k} at the facility end and relate them back to the residence district. For example, $\sum_j N_{ij}^{k} / N_{i*}^{k} X_j^{k}$ is a measure of the number of cases for the i-zone population, and so $1/P_i^{**} \sum_j N_{ij}^{k} / N_{i*}^{k} X_j^{k}$ is the appropriate per capita indicator. The corresponding facility is X_j^{k} / Z_j^{k} - i.e. it is related to catchment population. Once this distinction is made, indicators can be calculated which relate both to the welfare of patients by residence and the efficiency of facility-providing districts. In no case is it appropriate to take quantities like X_j^{k} / P_j^{**} and call them useful indicators - even though this is what is usually done. In this instance, the modelling contribution is decisive in the calculation of effective and meaningful indicators.

An interactive planning framework

The information system and model system described above has been embedded in an interactive planning framework - as described in Clarke and Wilson (1984). The system description is put together twice, as a base file and a current file, for comparative purposes, and performance indicators are calculated in each case. Because of the large number of indicators, a subset can be selected for on-line printing. It is then possible to specify a sequence of base file pictures representing exogenous change, such as demographic change, and 'agreed' changes of supply variables. In a run of the model, policy variables such as bed or budget allocations can then be manipulated on the current file for the same underlying sequence and performance indicators calculated in each case. Adjustments can then be experimented with and either retained or rejected according to whether desired improvements in performance indicators are achieved.

A commentary and appraisal system

It is obviously straightforward to compare current and projected performance indicators with any available norms and to print out any serious divergencies as part of the interactive planning system. This will at least provide food for thought. A more difficult task is to devise more intelligent responses. The beginnings of steps in this direction could be the calculation of resource dispositions across the region which are in some sense optimal. These could be compared with the current situation. One way to do this is to extend the model used to predict optimum retailing structures (Harris and Wilson, 1978, Wilson and Clarke, 1979, Clarke and Wilson, 1983).

For example, take the flow model given by (6) - (9). Let $\gamma_j^k(X_j^k)$ be the unit costs of providing k-treatment at j when the overall scale of provision at j is measured as X_j^k cases. This formulation then allows for the presence of scale economies. Then the total specialty cost is

$$C_j^k = \gamma_j^k (X_j^k) . \; X_j^k \tag{14}$$

and the number of patients treated are

$$D_j^k = \sum_i N_{ij}^k \tag{15}$$

Let Γ^k be the regional norm of cost per case. Then we can ask : what is the distribution $\{X_j^k\}$ such that all cases are treated at the regional norm? This is the solution to the equation

$$C_j^k = \Gamma^k D_j^k \tag{16}$$

In full, these are

$$\gamma_j^k (X_j^k) \, X_j^k = \Gamma^k \sum_i \frac{E_i^k \, X_j^k \, e^{-\beta^k c_{ij}^*}}{\sum_\ell X_\ell^k \, e^{-\beta^k c_{i\ell}^*}} \tag{17}$$

Cancelling X_j^k :

$$\gamma_j^k (X_j^k) = \Gamma^k \sum_i \frac{E_i^k \, e^{-\beta^k c_{ij}}}{\sum_\ell X_\ell^k \, e^{-\beta^k c_{i\ell}}} \tag{18}$$

These are nonlinear simultaneous equations in (X_j^k) and we have extensive experience of solving these in other contexts. This model would quickly identify subregional and regional specialties for instance by generating an (X_j^k) pattern with a relatively small number of non-zero X_j^k's for those k's.

5. CONCLUSIONS

It is by no means an exaggeration to state that the N.H.S. is in a state of flux at the current time. Almost daily there are reports in the media of one sort of problem or another affecting a Region or a District. Consultants plead for more money, emotively arguing that lives are at risk, while administrators point out that a District is several million pounds over its revenue allocation. Understandably, there is public outcry and demands that extra resources be made available. The problem is that given a fixed budget and ever increasing demands for services, stark choices have to be made. Between different types of services, between different districts and between regions, resource allocation decisions have to be made. There is little sign indeed that the N.H.S. budget will be effectively increased beyond the rate of inflation in the coming years.

Given this situation effective planning takes on a paramount role within the N.H.S., and at all levels. How quick various parties respond to the challenge that is now faced, to use resources equitably, efficiently and effectively will remain to be seen. The arrival of the new 'General Manager' in all authorities might prove the necessary impetus for the adoption and use of systematic planning methods. Geographers can help by promoting the wares of their trade in a positive and applied way.

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APPENDIX

Performance indicators and catchment populations

We argued in section 4 that there are two basic types of performance indicators relating to districts (or other zones) by residence and districts (or hospitals) by facility. Here we give examples of indicators calculated under each of these headings.

Residence-based indicators

* proportion of cases treated within a district, the next ring, and so on.
* hospitalisation rate : number of cases treated somewhere divided by resident population.
* notional beds available divided by resident population.
* notional expenditure on different types of health care divided by resident population.
* average distances travelled to facilities by residents.

Facility-based indicators

* proportion of facility patients who live in the same district, next ring, etc.
* beds per head of catchment population.
* expenditure per head of catchment population.
* treatment intensity rate : cases per head of catchment population.
* cases per bed.
* cost per case.
* average distance travelled to that facility.

Catchment populations

The concept of 'catchment population' is obviously crucial to the calculations of effective facility-based indicators. It can be calculated as follows, using the arrays defined in section 4.2.

Let h_j^* be the treatment rate for members of the catchment population of j. It can then be argued that this rate should apply to all elements of the catchment population so (for the aggregate case)

$$P_{ij}^* h_j^* = N_{ij}^* \tag{A1}$$

and

$$h_j^* = N_{ij}^* / P_{ij}^* \tag{A2}$$

should be independent of j. That is, we want an estimate of P_{ij} such that this holds.

From (A2), if h_j^* is independent of j

$$h_j^* = \sum_i N_{ij}^* / \sum_i P_{ij}^* \tag{A3}$$

$$= N_{*j}^* / Z_j^* \tag{A4}$$

But we also require

$$\sum_j P_{ij}^* = \sum_j N_{ij}^* / h_j^* = P_i^* \tag{A5}$$

So, substituting from (A4) into (A5) :

$$\sum_j \frac{N_{ij}^*}{N_{*j}^*} Z_j^* = P_i^* \tag{A6}$$

These simultaneous equations can be solved for the vector $\{Z_j^*\}$ and these catchment populations then have all the desired properties. It is straightforward to extend the argument to deal with specialty catchment populations by replacing the *-superscript by k.

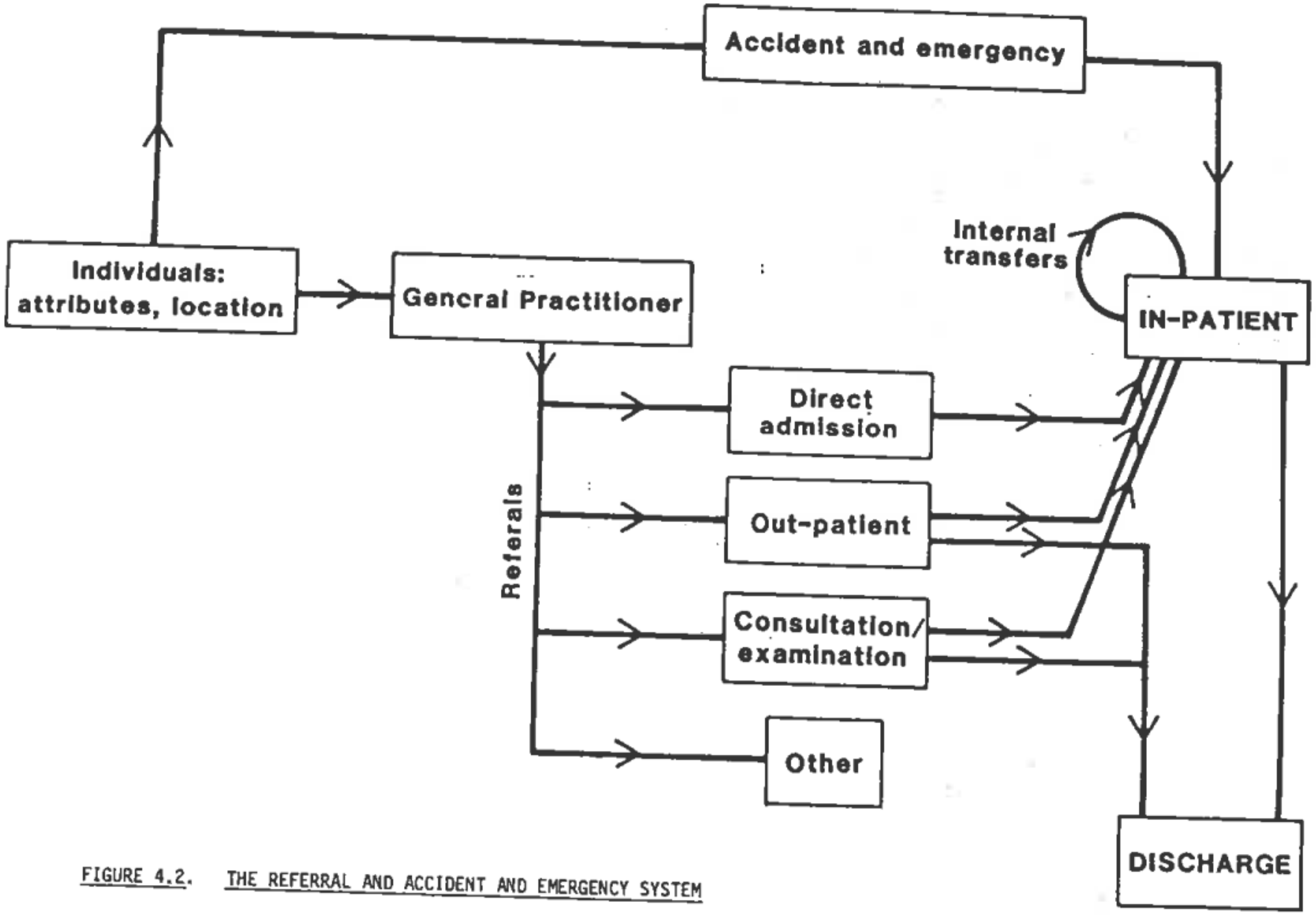

FIGURE 4.2. THE REFERRAL AND ACCIDENT AND EMERGENCY SYSTEM

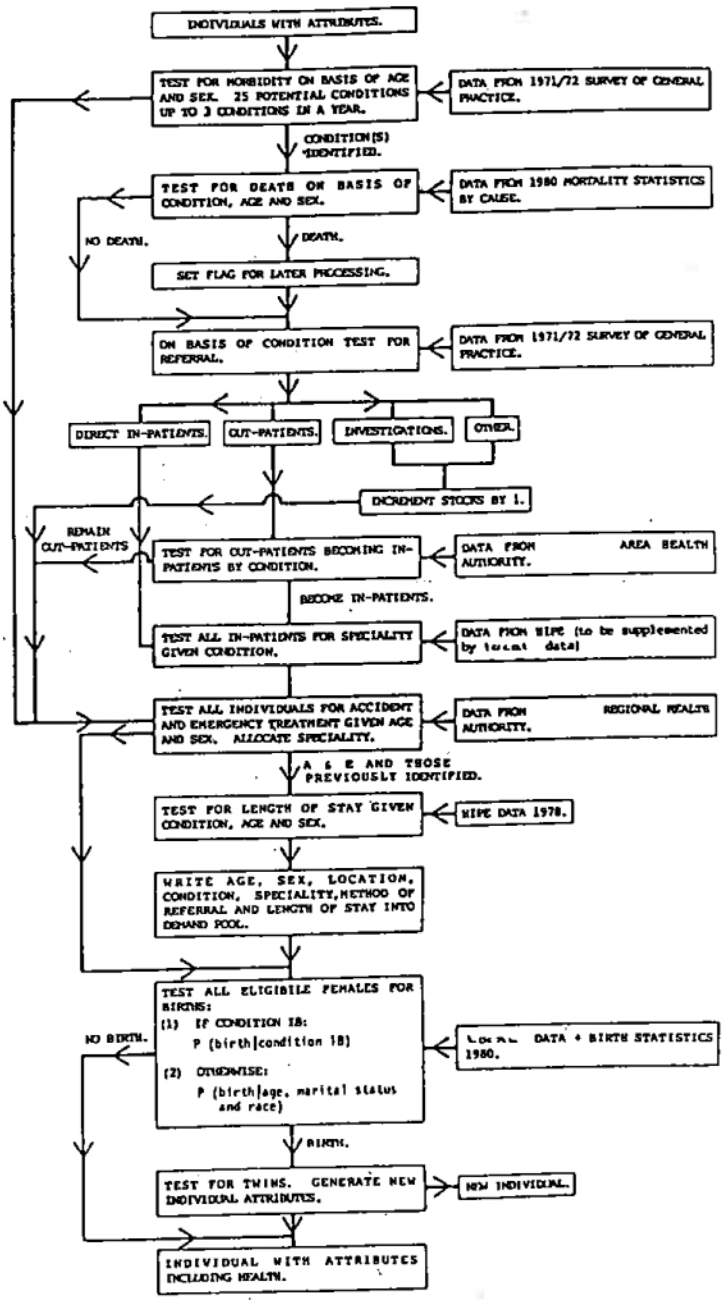

FIGURE 4.3. MORBIDITY MODEL

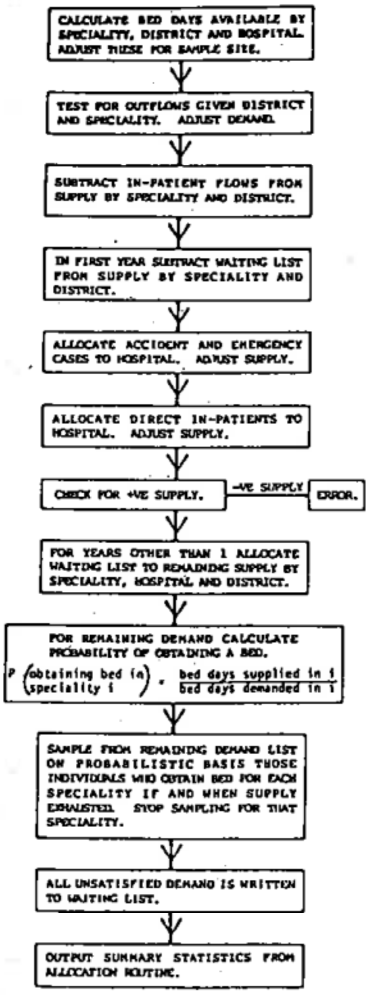

FIGURE 4.4. ALLOCATION MODEL

TABLE 4.1 ADMISSIONS BY SPECIALTY AND HOSPITAL

SPECIALTY	HOSPITAL 1	2	3	4	5	6
1	1392	1040	0	0	0	0
2	0	872	0	0	0	0
3	112	0	0	0	0	0
4	0	588	0	0	188	196
5	1588	2233	0	0	0	0
6	0	0	0	4	0	0
7	0	0	312	1172	0	0
8	248	0	0	0	0	0
9	576	868	0	0	0	0
10	0	380	0	0	0	0
11	0	364	0	0	0	0
TOTALS	3916	6345	312	1176	188	196

SPECIALTY	ACCIDENT & EMERGENCY	DIRECT	INDIRECT	TRANSFER
1	1064	836	532	[illegible]
2	116	244	512	0
3	16	24	72	0
4	184	148	408	0
5	692	700	2429	0
6	0	0	4	0
7	380	152	952	0
8	36	52	160	0
9	76	416	952	0
10	0	380	0	0
11	220	124	20	0
TOTALS	2784	3076	6041	0

TABLE 4.2. ADMISSIONS BY SOURCE AND SPECIALTY

TABLE 4.3

LENGTHS OF STAY BY SPECIALTY

LENGTH OF STAY	1	2	3	4	5	6	7	8	9	10	11
1	572	228	0	28	908	0	292	32	220	188	44
2	264	180	4	8	636	0	88	52	428	40	24
3	192	92	0	20	412	0	68	12	128	20	24
4	108	112	0	16	280	4	64	12	88	8	16
5	176	68	0	12	220	0	96	16	96	12	40
6	112	36	8	20	196	0	40	12	44	0	24
7	148	16	4	24	180	0	64	20	32	8	44
8	104	8	8	20	164	0	56	16	28	8	28
9	52	8	0	8	92	0	32	32	68	8	16
10	68	8	12	28	68	0	32	12	68	0	8
11	88	4	4	20	92	0	72	8	68	16	20
12	60	20	0	8	108	0	20	4	32	8	16
13	24	0	16	4	36	0	12	4	12	12	8
14	52	4	12	120	28	0	32	0	44	8	12
15	20	16	4	16	40	0	44	4	24	4	12
16	36	4	0	16	16	0	48	0	16	4	12
17	48	8	0	20	44	0	60	0	24	8	0
18	8	4	4	4	28	0	24	4	0	0	4
19	20	0	8	4	24	0	20	4	4	0	0
20	12	0	0	12	8	0	20	0	0	4	4
21-30	0	0	0	0	164	0	0	0	16	0	8
31-50	0	0	0	0	0	0	0	0	0	0	0
51-100	0	0	0	0	0	0	0	0	0	0	0
101-500	0	0	0	0	0	0	0	0	0	0	0
501-1000	0	0	0	12	0	0	0	0	0	0	0
>1000	0	0	0	24	0	0	0	0	0	0	0
TOTALS	2165	816	84	444	3745	4	1184	244	1440	356	364

TABLE 4.4 TREATMENT RATE PER 1000 OF THE POPULATION

SPECIALTY

YEAR	1	2	3	4	5	6	7	8	9	10	11
1	12.4	5.5	0.9	4.9	22.2	0.6	8.9	2.2	8.7	3.5	1.4
2	11.2	5.6	0.6	4.8	22.0	0.6	9.2	1.8	9.0	3.0	1.7
3	12.7	6.4	0.8	4.5	23.8	0.7	9.3	1.9	8.0	3.3	1.7
4	12.1	6.5	0.7	4.8	24.1	0.8	9.2	1.5	8.2	3.1	2.0
5	12.0	5.3	0.5	4.7	23.0	0.7	8.2	1.8	8.6	2.9	1.6
6	13.3	5.0	0.7	4.5	22.2	0.7	9.1	2.0	7.4	2.5	2.0
7	13.4	3.9	0.6	4.0	23.8	0.7	9.8	1.8	7.7	2.4	1.6
8	13.5	4.9	0.6	4.0	23.6	0.6	9.2	1.7	8.6	2.3	2.0
9	12.2	4.6	0.7	4.9	22.6	0.6	9.5	1.7	7.0	1.9	1.9
10	13.4	4.1	0.6	4.7	23.9	0.5	8.8	2.0	7.4	2.0	2.0
MEAN	12.6	5.2	0.7	4.6	23.1	0.6	9.1	1.8	8.1	2.7	1.8
S.D.	0.7	0.8	0.1	0.3	0.8	0.1	0.4	0.2	0.6	0.5	0.2

TABLE 4.5 EXPENDITURE PER HEAD OF THE POPULATION

SPECIALTY

YEAR	1	2	3	4	5	6	7	8	9	10	11
1	10.7	2.4	1.1	14.1	12.7	0.2	8.5	0.8	4.3	2.4	1.1
2	14.8	3.2	0.6	23.3	11.1	0.0	7.6	0.5	4.4	1.5	1.6
3	14.0	3.2	0.9	21.9	11.7	0.0	9.0	0.5	4.1	2.1	1.3
4	13.6	3.1	0.9	16.1	11.5	0.1	7.0	0.4	4.1	1.7	1.3
5	12.4	2.5	0.8	15.9	10.5	0.0	7.6	0.4	4.3	1.5	1.5
6	10.5	2.7	0.7	15.4	11.5	0.0	8.7	0.5	3.7	1.8	1.5
7	16.6	2.7	0.9	14.1	12.0	0.1	7.1	0.6	3.9	1.2	1.2
8	15.0	2.9	0.7	21.0	13.0	0.0	8.0	0.5	4.1	1.3	1.7
9	13.6	3.1	0.8	16.4	11.6	0.0	9.2	0.6	3.8	1.7	1.6
10	12.2	2.6	0.7	17.6	12.8	0.0	8.4	0.7	3.3	0.8	1.6
MEAN	13.5	2.8	0.8	17.6	11.8	0.0	8.1	0.5	4.0	1.6	1.4
S.D.	1.9	0.3	0.1	3.1	0.8	0.1	0.7	0.1	0.3	0.4	0.2

TABLE 4.6. AVERAGE NUMBER OF CASES PER BED

	SPECIALTY										
YEAR	1	2	3	4	5	6	7	8	9	10	11
1	19.5	34.3	14.3	4.1	42.6	9.6	16.7	26.3	44.4	29.0	21.5
2	13.8	35.1	9.1	3.9	39.9	3.5	15.9	16.6	40.8	24.5	28.1
3	20.4	41.1	14.5	3.6	42.8	2.5	15.9	18.1	39.0	26.8	25.1
4	19.5	41.9	12.7	2.9	42.6	4.0	15.5	16.3	40.4	25.2	26.7
5	19.5	34.7	9.8	2.8	40.9	4.5	13.8	16.8	40.2	24.2	25.3
6	21.1	33.3	10.5	3.3	40.9	2.5	15.5	17.1	35.3	20.8	28.3
7	21.9	27.8	10.5	3.5	41.9	6.0	16.5	15.5	36.9	19.8	23.7
8	22.1	31.1	10.2	4.3	42.9	0.5	15.8	16.5	39.0	19.0	30.3
9	19.2	31.3	10.2	3.9	41.7	3.0	16.1	16.5	33.8	15.8	28.4
10	21.1	28.4	8.7	3.9	43.2	3.0	15.6	22.8	34.4	16.0	29.8
MEAN	20.3	33.9	11.0	3.6	41.9	3.9	15.7	18.3	38.4	22.1	26.7
S.D.	1.1	4.5	2.0	0.5	1.0	2.3	0.8	3.3	3.1	4.3	2.7

TABLE 4.7 EXPENDITURE PER CASE

	SPECIALTY										
YEAR	1	2	3	4	5	6	7	8	9	10	11
1	824.3	418.0	1133.7	2493.9	551.3	327.1	885.6	349.6	431.6	681.2	707.7
2	1179.9	537.5	1002.6	4335.9	514.5	242.2	838.2	357.7	478.0	515.5	786.8
3	1024.8	464.7	949.5	4390.6	505.5	301.3	996.3	326.3	472.1	657.4	689.3
4	1194.0	439.2	1072.4	3938.6	499.4	341.4	796.2	273.3	449.1	543.6	656.2
5	955.3	430.0	1168.7	4150.4	475.8	219.7	967.2	241.4	479.8	505.7	826.2
6	744.2	475.0	934.6	3390.5	521.9	357.8	988.1	290.9	465.1	704.7	731.7
7	1131.5	564.5	1292.1	2903.7	528.6	337.4	750.5	415.2	469.6	514.1	695.7
8	1015.3	550.4	1067.9	3551.7	561.7	376.7	892.6	346.5	468.5	564.2	749.4
9	1056.3	577.5	1165.6	3026.9	514.3	251.1	995.4	384.9	506.9	860.7	750.5
10	867.0	529.7	1155.8	3225.2	546.9	329.6	946.2	335.5	423.8	387.5	752.7
MEAN	999.3	498.6	1094.3	3540.7	522.0	308.4	905.6	331.6	464.4	593.5	734.6
S.D.	144.0	56.7	105.4	614.2	24.8	50.4	83.5	49.0	23.0	127.1	47.3

TABLE 4.8

AVERAGE LENGTHS OF STAY

YEAR	SPECIALTY 1	2	3	4	5	6	7	8	9	10	11
1	10.0	4.2	17.8	66.5	6.7	3.5	14.6	6.5	4.9	6.8	7.1
2	14.6	5.4	15.8	128.5	6.2	2.6	13.2	6.5	5.5	5.2	7.9
3	13.1	4.6	14.9	137.5	6.0	3.2	16.2	6.0	5.4	6.6	6.9
4	15.2	4.4	16.9	116.3	6.0	3.6	13.2	5.0	5.2	5.4	6.6
5	11.8	4.3	18.4	108.9	5.8	2.3	15.3	4.5	5.5	5.1	8.3
6	9.4	4.8	14.7	104.2	6.3	3.8	15.4	5.4	5.3	7.0	7.3
7	13.6	5.6	20.3	89.6	6.4	3.6	12.1	7.7	5.4	5.1	7.0
8	12.9	5.5	16.8	101.6	6.7	4.0	13.9	6.4	5.4	5.6	7.5
9	13.7	5.8	18.3	81.6	6.2	2.7	15.7	7.1	5.8	8.6	7.5
10	10.5	5.3	18.2	91.8	6.7	3.5	14.8	6.2	5.0	3.9	7.5
MEAN	12.5	5.0	17.2	102.6	6.3	3.3	14.4	6.1	5.3	5.9	7.4
S.D.	1.9	0.6	1.7	20.4	0.3	0.5	1.2	0.9	0.2	1.3	0.5

TABLE 4.9

PERCENTAGE OCCUPANCY RATES

YEAR	SPECIALTY 1	2	3	4	5	6	7	8	9	10	11
1	61.0	39.3	69.8	94.0	78.0	9.1	66.8	46.6	59.9	54.2	41.7
2	64.1	51.8	39.4	96.6	67.8	2.5	57.8	29.6	61.4	34.6	60.6
3	76.0	52.3	59.6	97.8	70.5	2.2	70.3	30.0	58.1	48.4	47.3
4	81.1	50.4	58.8	100.0	70.3	4.0	56.0	22.5	57.9	37.6	48.0
5	65.9	40.9	49.4	100.0	64.6	2.9	57.9	20.5	61.0	33.5	57.3
6	60.1	43.3	42.4	100.0	70.8	2.6	65.4	25.1	51.6	40.1	56.8
7	72.6	43.1	58.7	100.0	73.5	5.9	55.0	32.5	54.6	27.9	45.1
8	76.2	47.0	46.9	100.0	79.3	0.5	60.3	29.0	58.0	29.4	62.3
9	69.5	49.6	51.2	100.0	70.9	2.2	69.4	32.3	53.4	37.3	58.4
10	66.6	41.2	43.6	100.0	79.3	2.9	62.9	38.7	46.8	17.1	61.5
MEAN	69.3	45.9	52.0	98.8	72.5	3.5	62.2	30.7	56.3	36.0	53.9
S.D.	6.6	4.6	9.1	2.0	4.7	2.3	5.3	7.3	4.4	9.9	7.2