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MODELLING FOR HEALTH SERVICES PLANNING : AN OUTLINE AND AN EXAMPLE

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1. Introduction

Health services, at a broad level, have the same characteristics as most other services. There is a demand (or expression of need) from a population, facilities are supplied, and there is some matching or allocation of the demand to the facilities. Since demand and supply are spatially separated, the planning task can be seen as a location-allocation problem: the location of facilities and the allocation of people from residences to particular facilities. (For a valuable review of the range of location-allocation problems, see Leonardi, 1981; for a general framework for studying service sectors, see Wilson, 1983.) However, we wish to emphasise from the outset that the conventional regional science approach is inadequate. There are few possibilities for the relocation of infrastructure or developments on new sites and so the policy focus often lies outside the conventional location-allocation approach.

Our task in this paper is to explore the range of modelling methods which can be brought to bear on the health services to provide an adequate analytical base for planning purposes. This will then help us to generate alternative plans and to test the impact of these plans. We need to produce evaluation indicators which will provide the basis for policy-making and monitoring. We will see that the full range of modelling techniques (for example as described in Wilson, 1981) can be brought to bear; but that, as is usually the case, it is the particularities of the service being considered which provides much of the interest. We need to devote much preliminary attention, therefore, to the adequate description of the health service rather than assuming that it takes some standard form.

The strategy for the paper will therefore be as follows. In section 2, we review the planning tasks (and associated problems) as they are perceived *at different scales* in the British health service (though we expect the ideas to be more widely applicable). We then examine (in section 3) in broad terms the techniques which are available for modelling, and we include a review of model outputs which can provide a major contribution to *information systems* for planning. We also, briefly, review other applications of modelling ideas in the light of our own framework. In section 4, we present a more detailed example to illustrate our own ideas: the modelling and planning of hospital services within a District Health Authority. We offer some concluding comments, particularly about priorities for further research, in section 5.

One final point in this introductory section refers to both the *multi*-disciplinary nature of much health service planning research and the need for an *inter*-disciplinary approach. A brief checklist of disciplines that address planning problems in the health service would include *at least* the following: health economics, social policy, geography, operations research, community medicine and accountancy. However, it is very rare that these disciplinary approaches are integrated into a unified framework. We would see this integration as a first step towards producing better planning frameworks and models and encouraging the wider collection, dissemination and use of information in planning. We shall argue in this paper that through adopting a systems analytic approach we can draw on the contributions from different fields in a coherent manner.

2. Planning and problem-solving in the health services

2.1 Introduction

As with many service sectors, the nature of the problem looks different at different spatial scales. We begin, therefore, by sketching the nature of the resource allocation and planning system as it now operates for the British health service (section 2.2). We then review some problems and associated planning tasks (section 2.3) and summarise the requirements to be sought from an associated analytical capability (section 2.4). Throughout the argument, we are conscious that health service policy-making is contentious and far from entirely a technical matter. We also need, therefore, to provide some understanding of the social processes involved as a background and the ways in which these are changing.

2.2 Resource allocation and planning at different scales

It is undoubtedly an important principle of resource allocation that it can only be made efficiently to a relatively small number of units, though what this number should be is a matter for speculation (and research?). In Britain, there are now three tiers of health service government following a reorganisation which was implemented in April 1982 and we focus on this rather than the earlier history. For completeness, we should also noted that there is an upper tier allocation from total government funds (represented by the Treasury) to the appropriate Ministry, in this case the Department of Health and Social Security (DHSS). The DHSS then allocate to regional health authorities (RHA's) and each region to district health authorities (DHA's). There are 14 regional authorities in England and varying numbers of districts within each region - in Yorkshire, for example, there are

16 districts. There are 193 districts in England with an average population of around 230,000.

The allocations from DHSS to regions is essentially financial and is formula-based (DHSS, 1976); this is also the case for the allocation from regions to districts (though there are some regionally supplied services - such as ambulance services - and some regional or sub-regional specialities which could not be efficiently supported in particular districts). The operational management and planning of health services is at the district level. There are then important scales within the district level - the creation of administrative units, for example, which are the basis of resource allocation within a district. These may represent different kinds of services - for example, community and hospital - or groups of hospitals within sub-areas of the district depending on the size.

For this system to work, there must be an adequate flow of information in both directions (compare, for example, the concept of Lange-Lerner planning described in Wilson, 1981, chapter 9). Part of the task of modelling, therefore, is to contribute to information systems at various scales which will improve this flow.

For the purposes of this paper, we focus mainly on planning tasks at the district scale because it is here that we need to establish indicators which also form the basis for those which can be used at regional and national scales.

2.3 Problems and associated planning tasks

We have seen that between the major levels of the health service, the major planning tasks are associated with budget allocation. For many years, these allocations were made on the basis of adjustments to historical allocations and on the whole there was enough growth to ensure that at least the most obvious new developments were implemented. In 1976, this changed, at the upper tiers, as a result of the Resource Allocation Working Party (DHSS, 1976). It has been recognised that earlier procedures were producing allocations which were obviously inequitable: the most powerful teaching hospitals for example, were relatively overfunded. The RAWP report proposed a formula basis which was then implemented with a phased progression towards RAWP targets. It is also possible to use the RAWP formula for the allocation from regions to districts, though it is interesting that many regions are now finding this inadequate (NAHA, 1983).

At the lower levels, within a district, the process of adjusting historical budgets still predominates. There are a number of possible reasons for this. First, it may well be in the interest of the most powerful groups (hospital consultants in certain specialties?) for this to continue to be the case. Secondly, the moves in other public sectors towards corporate planning and the explicit formulation of objectives which form the basis for budget changes has had little impact in the health services. Thirdly, and this may be a partial explanation for the second reason above, there are inadequate indicators on which policy can be based. This may be seen as a conceptual problem: an inability to devise appropriate indicators. Fourthly (and 'fuel' for the third reason), there is insufficient elementary data. This will emerge at a number of points in the discussion on modelling below, but a particular example is the inadequacy of cost data which obviously inhibits both policy-making and monitoring.

This situation is now bound to change for at least two reasons. First, even with relatively rough and ready indicators, the Black Working Party (Townsend & Davidson, 1982) found inequities and inadequacies which will begin to force reappraisal. Secondly, there is no longer enough growth money to fund obvious new developments. Indeed, the budgets of some district health authorities are now being cut in real terms. This means that the historical allocations have to be scrutinised and resources clawed back for problem-solving and the implementation of new developments. For this to be achieved, however, there must be a solution to some of the technical problems mentioned above: a better data base and better indicators, both integrated into an information system.

One of the most significant developments in terms of management information systems in the NHS will come with the implementation of the recommendations of the Körner Committee. Amongst other things, Körner has proposed the setting up of a computerised patient administration system at the district level. This should provide District Administrators with a much better picture of the way in which their care systems function. At the present time most information processing is undertaken by the Region and requests for special tabulations of information can often take a considerable period of time to be processed.

Within a district, the allocation of the budget between services and facilities can only be adequate if based on an intimate knowledge of the various modes of operation. In effect, it is necessary to know in detail the production functions of each element of the district system: the outputs which can be achieved for given (costed) resource inputs. This is necessary in the first place to demonstrate that each element is operating as efficiently as possible; and secondly, because this is the data out of which evaluation indicators can (in part) be constructed and used as the basis of policy appraisal. Against this background, typical planning problems can be identified at different scales within a district.

At the broadest scale, the budget has to be allocated between major sectors (units), say hospitals on the one hand and community services on the other. Government policy for a number of years has been to try to improve the position of the community services but this has been difficult because of the historically based procedures. There are some interesting interdependencies too. If insufficient is spent on services for the elderly in the community, there is likely to be an increase in the number of geriatric patients in hospitals. The cost of these alternatives need to be weighed against each other and set against the relevant benefits.

There are, potentially, some classic location problems. Where should a major new hospital go? What should be the spatial distribution of accident and emergency facilities? The first type of problem is relatively rare. The building of major new hospitals can not often be afforded, and when one is built, the choice of sites is usually restricted to land already owned by the health authority. Hence the use of classic location-allocation methods become redundant. The second illustrates a much more common type of problem: given the existing set of hospital buildings, how should specialties be distributed across them? For a given building, how should it be utilised - ie. what mix of specialties?

This may be viewed purely as a management problem with little spatial input. However it can be shown that these types of decisions often have important spatial ramifications in terms of who gets what where and who does not (see Clarke and Williams, 1982). For example the reduction of the number of beds available in a certain specialty may well lead to an increase in the waiting list. As a consequence GPs may respond by referring patients to other hospitals perhaps outside the district. This may entail longer and more costly journeys for the individuals involved.

At finer scales, there are other problems of a stochastic nature. A method of assigning beds to a specialty, for example, sometimes defines 'territory' which is not efficiently used. Careful planning of modes of operation is necessary to achieve an effective degree of flexibility.

We have already mentioned the need to be efficient within any particular element of the service. This means the effective planning of combinations of resource inputs in each case.

Finally, we note the problem of allocating patients to services. Quite often, there are alternative modes of care or treatment - as we saw in the case of the elderly above. These alternatives need to be articulated carefully, and the costs and benefits weighed. Typically, it will be appropriate to provide a mix in each case; 'variety' may be better than a simple view of the 'best'.

We also have to note that the nature of the strategic planning problems change with both the changing needs of the population and the alternative ways in which care may be provided. For example, the number of elderly persons (75+) in England is projected to change from 2.348 millions in 1975 to 2.967 millions in 1991, an increase of over 26%.and the 85 and over group is projected to increase by 33% (OPCS, 1978). This clearly implies an increase in demand for services for the elderly over the country as a whole. How this will reflect itself at the District level clearly depends on existing population distributions and future change. Hence districts need access to population forecasts produced at the appropriate spatial scale. Alternative forms of care and treatment may be considered for these elderly patients as policies and priorities change. We shall return to this question in section 4.

In section 4 below, we present the models which form the basis for tackling many of these problems within the context of a district health authority. We should emphasise that it is important to generate a framework which is comprehensive and not simply designed to tackle particular and isolated problems, the so-called disjointed incrementalist approach. In conclusion, we should also note that there are other problems which are regional or sub-regional (but multi-district) which can be tackled using similar ideas to those we present at the district level. This is an issue to which we will return in section 5.

We now turn to a broad review of the techniques which are available for modelling before proceeding to the examples in section 4.

3. Approaches to modelling

3.1 The main elements

The broad framework for a model system is shown in figure 1. The need or demand for health services is obtained by applying morbidity rates to a population model. The supply can be seen as the manipulation

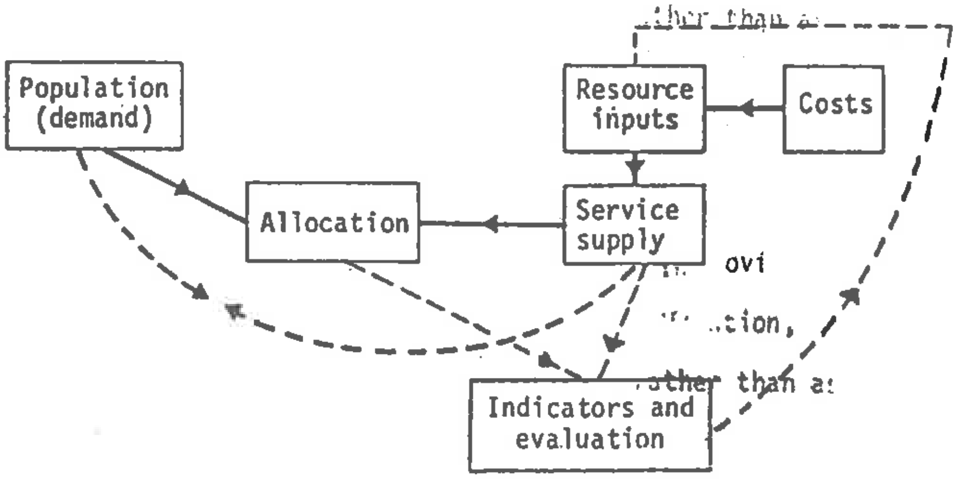

Figure 1.

of resource inputs to generate outputs (such as bed-days) by speciality in a facility at a location. These are costed and the three boxes on the left hand side of the figure constitute a representation of production functions. The allocation involves two stages (which may be executed simultaneously): the assignment of an ill-patient to a speciality (and possibly to one of alternative modes of treatment within or between specialities), and secondly to a particular facility at a location.

All approaches will contain these elements in some form or other. In the next subsection (3.2), we briefly review the range of techniques available and then (3.3) examine the range of approaches adopted in the literature. We outline our own approach in subsection 3.4 before presenting the model in detail in section 4.

3.2 The techniques available

At the outset we can note that there is a wide range of techniques that we can call upon to assist in the analysis and planning of health services. For convenience we can divide these into three groups: locational methods, management methods and methods from system analysis. There is a review of the basic techniqueswhich can be used for modelling in locational analysis in Wilson (1981). All have some role to play here but, as we will see, there is also a substantial part for systems analysis in a broader sense.

It is likely that in many cases, spatial interaction models will be useful, first to allocate users to services in at least some instances; and secondly, in association with embedding theorems, to help in the formulation of optimum plans. The concepts of accounting are also important, particularly in the building of a comprehensive model. This will enable us to keep track of all patients, resources and money, will ensure consistency in the models and will provide much of the basis for an information system. Optimisation methods are likely to be relevant in only a limited way, in location problems, as noted earlier, at least in terms of the location of major facilities because the resources for new buildings on new sites will not usually be available. There may be a possibility of formulating, as a mathematical programme, the problem of assigning specialties to existing buildings, but this depends on an in-depth understanding of the non-linearities of the cost functions involved. The techniques of network analysis will not usually be relevant except possibly for detailed planning of specific service sectors like the ambulance service (although the methods have been applied for example, to the allocation of specialities within a district by Duncan and Noble, 1979).

Finally, there is the possibility of using recently developed methods of dynamical analysis to analyse the structural stability of spatial configurations and to test this against likely future changes. It will also be of crucial importance to build a detailed dynamic population model to predict changing demand patterns and one effective way of doing this is through the micro-simulation methodology.

In order to implement any of the models implied by the availability of these methods, it will be necessary to put a lot of effort into conventional systems analysis. The detailed understanding of elements of the system, particularly, for example, the nature of the cost functions. A second example, to which we will return, is the detailed analysis of the process of allocation of patients to facilities. Of all the techniques discussed, therefore, it is likely that it is the concepts of accounting which will turn out to be the most important in this context.

3.3 Previous applications of modelling methods

In this section we discuss a range of existing modelling applications in health service planning. By necessity the review is selective and in any case there is a number of extensive accounts already available (for example, Boldy, 1976, 1980, Shigan, 1978). Here we take the opportunity to comment on some of the modelling applications, in relation to our earlier comments in section 2 of this paper; and to identify areas for further research. The framework around which this section is organised is presented in table 1, which is focussed on allocation problems at a number of different spatial and temporal scales. The examples and references quoted are each illustrative of a particular approach and are by no means exhaustive. We consider each of the different types of allocation problem in turn.

(a) Resources to regions. As we have already noted since the introduction of the RAWP method of allocating resources between regions an attempt has been made towards reducing the gross inequities in the overall distribution of resources across the country. Although not strictly a modelling exercise in itself, RAWP is formula based and represents an attempt to quantify the resources provided to regions in relation to their needs. This was to be achieved by comparing the age and sex distributions of regions and through the use of Standard Mortality Ratios (SMR). It was decided against using morbidity statistics relating to illness and to concentrate on the cause of death in regions. It can be argued, of course, that this decision is inadequate but it largely stems from the lack of adequate data on morbidity, a topic to which we return in section 5. Rather than provide a detailed critique of the RAWP method (and we can refer the reader to Bevan & Spencer (1983), in this volume) we consider two points only.

First, for any revenue equilisation system to work, the necessary political and managerial desire for it to work must exist. Secondly, if it does work the majority of complaints will come from those who lose relatively and they will be critical of the methodology used. This implies that while the methodology for allocating vast sums of money must be relatively sophisticated; and it must be well understood. (The same comment applies to the Rate Support Grant in the allocation of resources to local authorities in this country.) The crucial point remains the lack of information about the definition of, and specification of, need.

(b) Resources to specialties. The problem of allocating resources to specialties within an administrative unit has attracted much attention (see Gibb, 1977, for a review). Again we find problems with defining need and the relationship between demand and the supply of services. It has been pointed out by several authors (eg. Feldstein, 1967) that there is an intimate relationship between the amount of services provided and the apparent need for that service. As the amount of service provided increases, so, it is argued, does the demand, although clearly there is an upper limit at which saturation is achieved. Much research needs to be undertaken in this area to ascertain exactly what processes are at work.

Perhaps the most notable contribution to resource allocation at this scale has come from the IIASA health care systems team (eg. Gibbs, 1978, Hughes, 1978, Aspden, 1980). Their set of models have addressed the allocation of resources to specialties at a number of levels. However, in the implementation of these models, a number of problems have been faced - in particular the nature of the representation of the supply side. As we have already noted, the specification of an appropriate, more detailed, production function at this level would be a major advance.

(c) Physical infrastructure to locations. This group of methods come under the classic location-allocation umbrella, widely developed in regional science. These models developed out of management science methods, such as the warehouse location and travelling salesman problems. The appropriateness of public facility location methods has not often been called into question, perhaps because there are few real applications. Although the methdology has improved, and a greater deal of realism can be incorporated into the models (eg. Wilson, et al., 1981, Brotchie, Dickey and Sharpe, 1980) whether they are the best analytic tools for the practical problems encountered in facility location issues in the health service remains doubtful (as Leonardi, 1981, hinted in his review). One of the original reasons for developing location-allocation models was the so-called combinatorial problem - there was such a high variety of possible alternative locations and configurations it was argued, that only a computerised search mechanism could find the best alternative. But this may have arisen because we have a particularly simplistic view of the nature of planning issues, as expressed in these models, and it is this that results in such combinatorially rich specifications. It is more likely that, because of the constraints inherent in the planning process (eg. in terms of sites available), very few alternative designs or system configurations ever become feasible options (see Clarke and Williams, 1982).

If location-allocation models are of use it is probably in informing planners how the existing provision of services differs from an optimal one (suitably defined). Procedures for incremental change may then be adopted.

(d) Groups of patients to alternative forms of care. As we noted earlier one of the most pressing problems in the health service is the provision of different packages of care to certain client groups, particularly the elderly. For these groups of patients the problems are often multi-faceted, but require separate attention. For example, a frail elderly person living at home may need a home help, a visiting nurse and chiropodist, and meals on wheels. There is often the choice as to whether the patient requires residential care (and all these services provided at one location), hospital care (for some specific condition) or day care. An added complication is that these services are not provided by a single administrative authority, but usually two or more. And typically the amount of need in the community will always exceed available supply.

Here we have a classic regional science problem, characterised by complexity, spatial trade-offs, interdependence and a large number of constraints. As yet however little progress has been made in tackling it. The 'balance of care' model developed by McDonald, Cuddeford and Beale (1974) is a notable exception and is now finding application within the health service (eg. Mooney, 1978, along with Boldy and Howell, 1980). Contributions from regional scientists would be useful additions to the small number of developments in this area.

(e) Individuals to care types. Assuming we have developed an overall strategy for allocating resources at the macro-level within a health authority, how do we decide which individuals get particular forms of care? For many services this is a straightforward issue (eg. a patient with appendicitis is admitted to general surgery) but for the sorts of care packages described above where the attributes of both the patient and the service need to be considered the matter is not so clear cut. One feature of the current system is that many geriatric patients are occupying acute hospital beds for long periods when they would be better located elsewhere.

What is needed is an approach that relates the individuals attributes to care packages and a method for achieving this has been outlined by Clarke and Prentice (1982). This was based around defining an index of need for individuals and relating this to the total need as a whole. The derivation of the index was to be undertaken subjectively by medical and administrative staff and an allocation of need to supply performed. The effects of defining different indices of need could then be explored and different allocations derived. The planner could then assess the implications of different outcomes and pick the one that was thought most desirable.

(f) Groups of patients to hospitals. Under this heading we consider the use of spatial interaction models in allocating patients to hospitals. Examples of the approach include Mayhew and Leonardi (1981), Riley (1982) and Hall and Gibberd (1982). In these studies (and others), origin zones are defined on the basis of some administrative units and destination 'zones' are either individual hospitals or health authorities. Either distance, travel time or cost is used as the 'cost matrix'. In the normal gravity model tradition, it is assumed there is a trade-off between the amount or quality of services offered at a location and the 'difficulty' in travelling to that destination in relation to other alternatives. Most applications of the models have produced good estimates of flow patterns compared with observed data. This however is to be expected. It is when the models are used in a forecasting role that their applicability may be less good. This is because these models do not recognise the fine structure of the patient admission and administration system. In this country the majority of individuals arrive at hospital after first consulting his or her GP. It almost always the case that the GP will make the decision as to where to refer the patient. Before the patient is admitted he or she may visit a consultant's out-patient clinic one or more times. Direct in-patients are often taken by ambulance to the nearest facility at which treatment can be provided. To assume that a patient has some elasticity of travel demand in relation to many types of treatment seems inappropriate. However, at coarse levels of resolution, spatial interaction models may still give a reasonable description of these flows 'on average'. For a further and more detailed discussion of the use of spatial interaction models in health care planning see Clarke (1983).

(g) Allocation of costs to specialities

One area of health service planning that is attracting a great deal of attention is in determining the costs of providing certain forms of care at a fairly detailed level. This is particularly the case for acute hospital services (for a bibliography see Forte, 1982). Two approaches seem to have developed in this area: first an accounting approach that attempts to identify the factor inputs into a service and costing them (eg. McGee and Osmolski, 1979); secondly a statistical approach that attempts to estimate speciality costs from available information using statistical methods (eg. Ashford, Butts and Bailey, 1981, Coverdale, Gibbs and Nurse, 1980). There is no doubt that this area of research will grow in the future and its output will be of importance as inputs to other types of modelling approaches.

4. A simulation model of a district health authority

4.1 Introduction

In this section we present the details of a simulation model of the hospital services provided at the district level. The principle aim of the modelling exercise is to provide planners with a tool that will help explore the consequences of various policy proposals in relation to strategic planning issues. In this paper we can only briefly discuss the main features of the model and for further details we refer the reader to Clarke and Spowage (1982, 1983). Our philosophy in constructing the model outlined here has been to develop a tool of general applicability both in a spatial sense (it could be used in other districts providing the appropriate information was available) and in a disciplinary sense (the output from the model would be of use to different groups of people within an authority, eg. the Treasurer's Department, Unit Administrators, the DMT, planners and so on). The model has been designed, therefore, so that it can address a wide range of planning issues. This contrasts with some of the more specialised modelling exercises we reviewed in the previous section. We could also add a belief that interdependence has important effects in large complex systems and this is another advantage of a comprehensive approach.

The application we describe in this section has been constructed in cooperation initially with the Kirkless Area Health Authority and more recently the Dewsbury District Health Authority. To a large extent we have used data that is either published in official publications or collected by the authority as a matter of course (eg. HAA data). However in certain cases data has not been available at the District level and recourse to either national or regional data has been necessary.

The model consists of four main components. First, we have a model of population dynamics in which we annually update the characteristics of the District population. Secondly, a morbidity model converts these characteristics into demand or need for hospital care. Thirdly, there is a model of the supply side which represents the type and amount of care that can be provided at various locations for different conditions and client groups. Finally there is an allocation model which allocates need to supply and generates a set of indicators both in terms of care provided and resources consumed. We describe each of these in turn and present some early results from our work.

No attempt is made within the existing framework to embed any optimisation methods. We believe that it may be possible to construct a fairly crude mathematical programming model for the allocation of resources between important groups of services (eg. between acute and community care, or between hospitals). We also believe that operations research methods are an important tool for a number of management issues. Both these approaches could be built in to our existing set of models (see Clarke and Prentice, 1982 and Wilson and Clarke, 1982, for details). However we also are of the opinion that it is useful to construct models that allow planners to explore the consequences of their decisions in some detail. The approach outlined here allows for this possibility.

4.2 Population dynamics

The population component of the model consists of two parts. First, we synthetically generate a sample of individuals and households together with their associated attributes that we consider to be of interest. Secondly, we successively update the attributes of this sample for each year of the simulation exercise, using micro-simulation methods.

The reasons for specifying a population at the micro-level have been justified elsewhere (Williams and Clarke, 1983, Clarke and Spowage, 1982) but a brief summary of these points is useful at this stage. In considering the need for health care a large number of individual factors may be relevant. Obviously age and sex are prime contributors to morbidity differentials in the population, but factors such as marital status, location, occupation, household structure and so on may also be of importance, as may be the inter-relationship between these variables. In addition, in addressing the issue of population dynamics we may wish to focus on the *variability* between individuals and households in the way in which this affects the various transitions between states. All these factors imply that the representation of the factors in our model will be an important issue. A micro-level representation is a highly efficient method for handling variability and interdependence, particularly because in most cases only a sample of the population is required to represent the full range of information about the population and, compared with the traditional occupancy matrix, contains no zero entries.

A micro-level representation of the population involves generating lists of individual and household attributes for a sample of the population. An example of this is given in table 2. Two methods for deriving these lists can be considered. First, we could sample from the population in an Authority but this would usually prove expensive in time and resources. An alternative is to use statistical synthesising techniques to generate a joint probability distribution of household and individual attributes from which a population can be sampled using Monte-Carlo methods. The method involves generating this joint distribution in such a way as to be consistent with any available information on the conditional and marginal distributions of attributes. These may be obtained from sources such as the census, the Family Expenditure Survey, the General Household Survey and so on. For a full description of the theory of the method see Clarke and Williams (1983) or McFadden et al. (1977).

In our application we employed this synthetic sampling approach, making considerable use of the 1981 census, in addition to other sources. A list of attributes generated is given in table 3. Tables 4, 5 and 6 present some comparative results between the model outputs and known distributions for Kirklees in 1981. These were generated using a sample size of 5,000 households, representing about 13,000 individuals. Table 4 contains the observed and predicted age and sex distributions and considering that some data used in generating this distribution was for 1971 (the 10% household data for 1981 not being available at the time of writing) the distribution is reasonable. Tenure split, shown in table 5 is almost exactly right and the spatial distribution of population (table 6) also shows a close matching. None of the 'actual' distributions in these tables were direct inputs to the model structure.

Given an initial population, one of our modelling tasks is to update its characteristics each year, of a (say) ten year period. We have already noted some key demographic trends and with the next census not scheduled until 1991 it is essential that we attempt to model demographic change during this period. To achieve this we employ a micro-simulation model; we test whether each individual or household is eligible for certain demographic transitions and then determine whether they occur, again using Monte Carlo sampling. To run the model, we require information on the conditional probability of an event, birth or death whatever, taking place as a function of certain individual or household attributes such as age, sex, marital status, race, and so on. Much of this is obtainable from published data though often not at the appropriate spatial scale.

Given that we can obtain these conditional probabilities in one form or another, we can process each individual and household on our list through a series of events. The following events are considered for each eligible household and individual: birth, death, marriage, divorce, net out-migration, leaving home, residential relocation, labour market transitions (retirement, redundancy, school leaving, job change, re-entering labour market). For a full discussion of the model used see Clarke and Spowage (1982).

4.3 Health care demand: a morbidity model

We have outlined in the previous section how we deal with generating a sample population and ageing it over time. We now turn to discuss how we model the demand for health care, restricting ourselves to hospital services at this stage, and, in particular, in-patient treatment. This discussion follows Clarke and Spowage (1983). Agreeing upon what is meant by 'the demand for health care' is extremely problematic, not to mention attempting to construct a model of it. A range of studies have attempted to identify the factors that influence the variations in demand for health care between different groups of individuals, between and within different regions of a country and so on. One very important distinction to make is between revealed demand and latent demand. Revealed demand is a measure of the number of people who received treatment for a particular condition: latent demand can be defined as the number of people with a certain condition, identified as such by the health system *or not*, who require treatment according to some predetermined criteria. The problem is that in using revealed demand as a measure of need we ignore those requiring treatment but not being diagnosed. Many studies (notably Feldstein, 1967) have commented on the relationship between demand for treatment and the supply of care facilities. They note that as the level of supply increases, as measured say by the number of beds provided, there is an almost inexorable rise in demand. However, the demand they are considering is revealed demand not latent demand. Without entering into a medical debate it may be argued that latent demand for treatment is fairly constant*, especially over the sort of time scales we are considering and the important factor to investigate is the way in which this latent demand is transformed through diagnosis, new forms of treatment and so on into revealed demand. This is clearly a complex phenomenon outside the scope of this paper.

There is a diverse number of ways by which an individual may arrive at a hospital for treatment. Figure 2 outlines the main flows which we consider. We distinguish between these various flows for the following reasons. Firstly, there are clear differences between many of them. The referral system, by which an individual originally consults his GP and, depending on the outcome, is referred to one of several medical channels of treatment, is a very different process than say the accident and emergency system. When it comes to examining policy options and identifying controllable variables this distinction becomes important. A second factor relates

*For example, just as many individuals may have been deemed suitable for a heart transplant 20 years ago as today.

to data availability. The Hospital In-Patient Enquiry, a major source of information on health care, provides information only on revealed demand - that is, individuals who receive treatment in hospitals. However, we are more interested in the general morbidity characteristics of the population, together with information on the referral system. This then allows policy options, such as alternative treatment types, to be examined. The only comprehensive morbidity data available for England and Wales is contained in two publications - Morbidity Statistics from General Practice, 1970-71 and 1971-72 (DHSS, 1979). These include data on all visits to a small sample of GP's in the respective years. From this data it is possible to generate conditions and outcomes (in terms of referrals) for individuals on the basis of age and sex but only at a national level. We supplement this data with local data where appropriate. More specifically the morbidity data gives us two useful types of information:

(1) The number of episodes, consultations and persons for each of 26 diagnostic groups by age and sex (shown in table 7). Episodes are the medical events - from first consultation to 'discharge'. Consultations are the number of visits by a patient to a GP and persons are the number of individuals involved. This information allows us to introduce multiple events into our model - this acknowledges that a person may be ill with the same condition more than once in a year.

(2) The outcomes of visits to GP's given condition. The following rates are identified for each condition:

(a) Referral rate - percentage of all patients referred for a given condition

(b) In-patient rate

(c) Out-patient rate

(d) Investigation rate

(e) Local Authority informed rate

(f) Other

Thus we can sample for each individual the outcome of a visit to a GP. The nature of the condition, and the outcome would then become extra individual attributes. In the present model we allow for up to three conditions being identified in any year.

However, this morbidity data provides us with information on only a subset, albeit a large one, of all the demand for hospital services. As can be seen from figure 2 not all patients arrive via the referral system: accident and emergencies typically form a significant proportion of in-patient flows. For these flows we must return to Health District data where information on accident and emergency admissions is available. The additional flows in figure 2, such as transfers, we also obtain from local data.

It can be seen from figure 2 that not all the possible flows in this system have been identified. For example, in-patients who become out-patients are ignored. This is because at this stage of model development we restrict ourselves to in-patient care. In addition, in the first simulation period, we will have to account for the existing waiting list, which we obtain from the Health Authority, by specialty.

The full morbidity model is outlined in figure 3. One important aspect of this framework is transferring morbidity conditions into demand for treatment in a specialty. Clearly an individual with a certain condition (say a malignant neoplasm) could be treated in either general medicine, general surgery or radiotherapy. Also in some districts where a certain specialty may not exist, people, who in other areas may get treated within that specialty, may get treatment in general medicine or surgery. The data for performing this transformation from condition to specialty is obtainable at a district level from the Hospital Activity Analysis.

Of course an extra component of demand arises from those individuals living outside the area but receiving treatment within the area. These cross-boundary flows may form a significant proportion of demand for certain specialties (for example in Kirklees, 17.3% of adult patients treated for mental illness at Storthes Hall Hospital came from outside the area) and when a regional speciality is located in an area. With reorganisation in April 1982 and the scrapping of the Area Health Authorities, the proportion of cross-boundary flows between the new authorities can be expected to increase just as their size has decreased.

4.4 Supply side model

In constructing a model of the supply side of the hospital system we are faced with the complicated task of determining how the various inputs into a hospital, in terms of manpower, and resources of different types, are transformed into the provision of medical care of various forms. Many direct analogies can be seen with an input-output framework. The 'final demand' may be the provision of bed-days for a given specialty. In effect, we have to articulate a complex production function. This relationship between supply and inputs is clearly not linear: sometimes a marginal increase in supply can be provided with few resources implications (when there is some slack in the system) but on other occasions a small increase in supply may imply a substantial increase in inputs (for example if a new consultant had to be appointed). In addition in certain situations an increase in one input (say beds provided) will only allow more care to be provided if the appropriate range of other inputs is increased (say operating theatre time available). This is why we often find in summary statistics specialties with low bed occupancy rates yet long waiting lists.

The costings of resource inputs, in terms of say the in-patient costs per bed day, by specialty and hospital, is an important task. As we noted in section 3 much work has been undertaken in recent years to develop methods for achieving costings. For our own purposes we have developed an accounting framework that utilises all published information on district costings to derive bed day costs (the method is fully described in Forte and Wilson, 1983). For each in-patient we are then able to determine the total cost of in-patient treatment.

In our current model we have not, as yet, built in a full representation of the supply side: we focus on bed days produced by specialty by hospital and we trace the underlying accounts linking these to resource inputs and costs. We regard the extension of this side of the modelling effort as the next major task.

4.5 The demand-supply interface

In allocating demand to supply at the area or district level extensive use has been made of Hospital Activity Analysis data. In particular, the mapping of patients' conditions (and specialty) into a particular facility will depend very much on local factors. The demand component of the allocation procedure consists of the following main groups:

(i) *Direct in-patients:* We assume that all this category have their demand satisfied.

(ii) *Accident and emergency patients:* once again we assume that this category are directly admitted.

(iii) *Out-patients who become in-patients:* the majority of this category are either placed on the waiting list or become 'booked and planned' patients.

(iv) *Waiting list:* this consists of two separate components: the beginning of year list and those who get added to it during the year. We assume that those who have been waiting the longest with a given condition and specialty get treated first.

(v) *In-flows from outside districts:* as the figures on these are an expression of revealed demand we assume that they all get treated.

(vi) *Internal transfers:* the probability of an in-patient being transferred once admitted is taken from HAA data.

The allocation procedure is outlined in figure 4 (and discussed in greater detail in Clarke and Spowage, 1983). Once a patient has been assigned a bed the probability of being admitted to a certain hospital is derived (from HAA data) and the length of stay determined in the basis of condition, age and sex. That number of bed days is substracted from the total available supply. If no supply is available the patient is admitted to an alternative location, if available, or if not, put on the waiting list. For each in-patient the cost of treatment is calculated from our specialty costing data. When all potential demand has been processed a variety of summary statistics are output.

We can recall from our earlier discussion of the micro-simulation approach that the information stored within the list processing representation could be cross classified in any way required. This allows for a large number of indicators to be produced and we discuss the implications for their use in planning in Section 5. A number of examples of these are presented in tables 8, 9, 10, 11 and 12. Table 8 gives the number of in-patients by condition, age and sex for the first simulation period. Table 9 is the cross-classification of conditions by specialty, again for the first year, and table 10 gives the types of operation for each of 12 specialities. Turning now to resource implications, table 11 presents the cost by Hospital and speciality in the first year and table 12 the distribution of costs by age and sex for the same period. We emphasise that these are only illustrative at this stage as further model development is in progress.

4.6 Summary

We have briefly outlined an approach to modelling in-patient care in a district health authority. The model could certainly be extended to other forms of care, perhaps most importantly to look at joint care issues where the relevance of alternative packages of care is most noticeable. The fact that many assumptions had to be made concerning the way in which the in-patient system operates reflects the lack of information available about the health care system. It is often argued that if more information was made available there would be no use for it. This is certainly not the case but there is something of a chicken and egg situation operating here. Effective planning models have not been widely disseminated and often the reason for this is the lack of adequate information. It is then argued that because there is little *use* for systematic information processing there is therefore little incentive to devote resources towards producing it. We show in the next section that, given adequate data and model outputs, we can construct an interesting range of indicators which have substantial uses in planning.

5. The operation of a model system for planning: conclusions and directions for further research

5.1 Information and planning: an overview

In this section we examine the use of information in health service planning and management, once again mainly concentrating on acute care. This is done in the context of the current concern with the generation and use of information and indicators in the N.H.S. and we aim to show how model development can make a major contribution. As we have already mentioned, in recent years we have witnessed both the evolution of the RAWP system for allocation of resources to regions and the Black report on inequalities within the N.H.S. Both these were heavily reliant on the use of indicators as expressions of need, inequity, overprovision and so on. At the district level, waiting lists and overall budgets have traditionally been the main general policy indicators which have been used. There is now pressure for Authority's to use a much wider range. This arises from the Annual Review each District has with its region; from the scrutiny of D.H.S.S. auditors who develop their own indicators - for example on operating theatre costs; and from other national pressure - for example, the list of indicators suggested in the recent government paper Health care and its costs (D.H.S.S., 1983). In the short run, indicators have to be obtained from available data; in the longer run, we have the Korner committee (D.H.S.S., 1982) which has set out to examine what range of information should be collected by the N.H.S. for different components of the overall care system and, as we will see later, this will improve data bases for the construction of indicators.

All these developments have occurred in parallel with the rapid growth of information technology (I.T.) - the development of capacity to handle information - together with the changing foci of concern within the health service planning system outlined in section 2.

At the outset, it is useful to distinguish between the collection and generation of data and information and the use of that information in planning. For some time now a vast amount of information has been collected on hospital in-patients, their conditions, their treatment and their outcomes, both through the Hospital Activity Analysis (H.A.A.) surveys and the one-in-ten sample collected for the Hospital In-Patient Enquiry (H.I.P.E.).

However, relatively little use of this information is made by decision makers at district level. Some important indicators are derived, such as waiting lists, average lengths of stay, occupancy rates and so on, and these are (usefully) compared with previous years' figures, those of other Districts and Regional averages. What has only recently begun to emerge is a move towards performance indicators which more explicitly relate the care provided to the level of resource inputs and the needs of the community. *Health care and its costs* represents a step towards this, but only a preliminary one.

What is clearly a first requirement for an information system is a framework into which it can be embedded. Figure 5, based on Calvert (1980), provides a useful starting point in this respect.

The objectives that an authority adopts will relate to the existing provision of services, the perceived level of current and future need and the resources at its disposal. These objectives will be translated into resource allocations to various sectors of the health care system. Resources are then used to provide various types of care. This utilisation will take the form of both capital and revenue expenditure. The resources provided through this process (buildings and equipment, staff, and medical supplies for example) are translated into a care system to meet identified need. The combination of inputs, and the way in which they are managed, will determine precisely how the demand for care is met and the outcomes produced. These can then be compared with the objectives set out at the beginning of this cycle.

There are two uses of this framework. First, it demonstrates how a modelling approach can be useful in determining how far policies (resource allocations) meet objectives. Second, it demonstrates how different types of information are required at various stages in this process. For example if we wish to improve throughput in a particular specialty, we need to know how a marginal increase in resources will manifest itself in increased levels of service supply. As we have emphasised throughout this paper unless we have detailed knowledge of the production functions of the specialties concerned, this will be a difficult goal to achieve. This level of detail is still not achieved in *Health care and its costs*. Another important point is that indicators of outcomes will have to be derived in the same language or form as the objectives that are set - or vice versa! - for obvious comparative reasons.

This has at least two implecations for planners. Objectives must be stated in terms that are susceptable to assessment, rather than bland statements of intent. Secondly more thought must be put into the design of indicators that allow an objective assessment of success or failure in this respect, as opposed to crude indicators such as waiting lists by specialty.

We now argue that these general problems can be tackled more effectively using the kind of model we sketched in section 4, and we now turn to this topic in the next subsection.

5.2 Models and information systems for health services planning

The first point to note is that the use of a model system such as that of section 4 is compatible with the scheme sketched in Figure 5. Objectives are formulated in the light of outcomes - as represented by a set of indicators; resources are allocated and deployed by a set of management decisions (the y-variables of our earlier paper - Clarke and Wilson, 1982); the outcomes of this deployment of resources can be calculated in the model. In effect, the model adds a lot of detail to Figure 5 and it is to this that we now turn.

The deployment of resources in all forms constitutes a detailed specification of the state of the supply side of the health care system. This, together with some parts of the model, adds up to a specification of a set of production functions: given the resource inputs, what can each specialty (or whatever) offer - say in in-patient bed days per annum? The demand side of the model represents a set of needs to be allocated to this supply. The allocation submodel matches demand to supply, estimates waiting lists or surplus bed days, and so on.

The simplest use of the model is therefore to compute, for a set of resource inputs, a set of indicators which describe the outcomes - the matching of demand and supply. The policy makers of an authority can then use the model to explore the effects of changing the pattern of resource inputs. Really, it should be possible to do this in an interactive mode with the computer. We should also add that in some cases (perhaps particularly at the inter-district scale) it should be possible to embed this system within an optimising framework so that it is possible to offer - at least as guidance - a 'best' disposition of resources.

It is misleading, however, to imply that this kind of model-based planning system is simple to build or necessarily simple to use. We therefore structure the rest of this discussion in this subsection as follows: first we examine and emphasise the increased detail of a model-based indicator set relative to more conventional alternatives; secondly, we discuss some of the complexities of these procedures in practice; thirdly, we discuss the liaison aspects of this kind of planning; fourthly, we summarise the discussion in terms of the kind of planning framework implied.

(i) Indicators as the basis for an information system.

The first point to emphasise is that on the one hand, the resource inputs are all costed - at least with the appropriate unit or average costs - and on the other, the demand side is represented by a realistic population of individuals. And there is a detailed connection from each side of the model to the other. No information is lost and so summary indicators can be much more detailed than is the case if raw data is used. We can illustrate this by comparing what is possible with our particular model-based system with the kinds of indicators listed in *Health care and its costs* (H.C.C.). We restrict ourselves to acute hospital services. HCC breaks these indicators into three categories: activity, financial and manpower. The activity indicators are by very broad specialty groups (medecine, surgical etc.), and we would hope to have much more detail. They then have numbers of admissions, average length of stay, measures of bed occupancy and waiting lists among others. We could break these down by residential location, social class, occupation or whatever for finer specialty groups and we could connect these activity measures explicitly to the supply side and hence give unit costs. The financial indicators are obtained by hospital category: costs per day, per case by hospital etc. Again, we aim to produce specialty costs and to be able to relate these to the unit of resource inputs and the unit costs of these in each case. This gives a better basis for judging likely direction of change. The manpower indicators are to a major extent concerned with nursing staff per in-patient day and so on. We would hope to be able to cover all categories of staff because we use this information as part of our costs model. So again, everything connects: we can give nursing requirements by specialty by hospital and cost them and say which patients (by their characteristics) they are working for.

In effect, we have a comprehensive and detailed accounting system which keeps track of resources, money, supply units and allocations to demand, and retains all the connections between them.

(ii) Some complications.

The scheme sketched out above represents a kind of cost-effectiveness analysis - with the evaluation of effectiveness ultimately left to judgement when the indicator sets are appraised. This would represent a considerable improvement on present practices. However, we should recognise that we need to pursue notions of marginal or opportunity cost where relevant instead of simply average costs worked out from annual budgets or whatever. In some cases, it might be possible to tackle more explicitly the task of benefit measurement.

The model in its present form will often build in apparent indivisibilities - like the assignment of a ward of so many beds to a particular specialty - which should be considered to be variable. In other words, for instance in the allocation of beds to specialties, there may be a need for more flexibility to achieve efficiency, but more detail needs to be built into the model for us to be able to represent this.

Finally, we are also aware that relatively simple-minded assumptions are made in the allocation of patients with certain conditions to modes of care. At present, we use allocations which are based on the proportions of current practice. In some cases, we need to recognise higher degrees of interdependence which are important for policy. For example, an additional consultant geriatrician may improve assessment procedures in such a way that a number of geriatric-ward beds can be vacated; these in turn may then be filled by long-stay patients who are 'blocking' beds in medical wards. This would be a new resource input and a policy change which would then alter the proportions of the elderly flowing into different modes of care.

(iii) Liaison.

It should be explicitly recognised that there will be many conflicts of interest in the planning system implied by the ideas presented here - or, indeed, in any other planning system. There will not be enough resources to satisfy all demands; it will be very difficult to make changes unless senior medical staff can be part of any agreement to do so. For this reason, the notions of planning teams and planning agreements taking in the different parties involved, as representing a continuing interaction, are very important. The information system described here should provide an effective basis for such arrangements.

(iv) A planning framework.

It is convenient to summarise the argument so far in terms of the kind of shift implied from the present position. At the core of the planning framework is an information system, a set of regularly updated indicators which provide the basis both for management and for strategic planning. In the latter context, these indicators provide the basis for the development of explicit objectives. The effects of changes in resource allocation can then be explicitly explored on the computer (and the real consequences monitored and the model adjusted if need be). The information generated can be the basis of planning agreements between the different interests involved and can provide foci for negotiation. It is also useful to add that machinery will often be needed to ensure that the usual practice of proceeding with very minor adjustments to historical allocations is changed. For example, it may be necessary to have groups which review all posts as they become vacant. A case would have to be made explicitly for refilling. Decisions would be taken in the light of planning agreements but would also add a finer scale of scrutiny to planning teams.

Finally, we note that this part of the discussion has been mainly couched, at least implicitly, in terms of district-level planning. The information system could be ammended to be useful both at a broader scale (regions, or small systems of districts) and a finer one (district units, or single hospitals).

5.3 Directions for future research

It is important to recognise that both short run and long run strategies are needed. In the long run, we can look forward to the implementation of the Kôrner recomendations and hence have better data bases. It will be increasingly possible to take advantage of advances in information technology.

We can also look beyond Körner: there is a need to link the G.P. patient administration system with that of hospital in-and-out-patient systems. This must be the next step forward if we are to progress in terms of overall management of health care and also to achieve an understanding of how the system actually operates - particularly with respect to allocation. In the short run, we have to make the best of what is available to us. This means finding effective ways of combining data from different sources and being able to make reasonable estimates when direct data is not available. An example of the latter is our approach to specialty costs. There is also an advantage in trying to develop a comprehensive framework because this provides an overall accounting basis and some missing quantities can be estimated as residuals. It will also be necessary within this, of course, to carry out detailed cost effectiveness analyses of particular projects.

Thus the research strategy implied by the present position is as follows. Develop a comprehensive information system which is regularly updated and continually seek to improve both the data and the modelling techniques which form the basis of its validity. And perhaps most importantly of all: embed this information system in planning and policy frameworks which are used. It is pressures from this use which will force an adequate information system to emerge in the end.

References

Ashford, J.R., Butts, M.S. and Bailey, T.C. (1981) Is there still a place for independent research into issues of Public Policy in England and Wales in the 1980's? *Journal of the Operational Research Society*, 32, pp. 851-

Aspden, P. (1980) The IIASA health care resources allocation submodel: DRAM calibration for data from the S.W. health region, U.K. Working Paper 80-115, IIASA, Laxenburg, Austria.

Bevan, R.G. and Spencer, A. (1983) Models of Resource Policy of Regional Health Authorities, this volume.

Boldy, D. (1976) A review of the application of mathematical programming to tactical and strategic health and social service problems. *Operational Research Quarterly*, 27, pp. 439-448.

Boldy, D. (Ed.) (1980) *Operational Research Applied to the Health Services.* Croom Helm, London.

Boldy, D. and Howell, N. (1980) The Geographical Allocation of Community Care Resources - A Case Study. *Journal of Operational Research*, 31, pp. 123-129.

Brotchie, J.F., Dickey, J.W. and Sharpe, R. (1980) *TOPAZ - General Planning Technique and its applications at the Regional, Urban and Facility Planning Levels.* Lecture notes in Economics and Mathematical Systems, 180, Springer Verlag.

Calvert, J.R. (1980) Relative Performance, in *Indicators of Performance*, Ed. D. Billing, Surrey Society for Research into Higher Education, University of Surrey, Guildford, Surrey, pp. 65-72.

Clarke, M. (1983) A critique of the use of spatial interaction models in health care planning and analysis. Working Paper, School of Geography, University of Leeds.

Clarke, M. and Prentice, R. (1982) Exploring decisions in public policy making: strategic allocation, individual allocation and simulation. *Environment and Planning, A, 14*, pp. 499-524.

Clarke, M. and Spowage, M. (1982) Specification of a microsimulation model of a District Health Authority. Working Paper 338, School of Geography, University of Leeds.

Clarke, M. and Spowage, M. (1983) A District Health Authority simulation model: The in-patient sub-model, specification and first results. Working Paper, School of Geography, University of Leeds.

Clarke, M. and Williams, H.C.W.L. (1982) Spatial organisation of activities and the location of public facilities. Paper presented at the Workshop on "Spatial Choice Models in Housing, Transport and Land Use Analysis" IIASA, Laxenburg, 1982.

Clarke, M. and Williams, H.C.W.L. (1983) Synthetic sampling methods and the generation of initial populations. Working Paper, School of Geography, University of Leeds.

Coverdale, I., Gibbs, R., and Nurse, K. (1980) A hospital cost model for policy analysis. *J. Operational Research Society*, 31, pp. 801-811.

D.H.S.S. (1978) *Report of the Resource Allocation Working Party*, H.M.S.O., London.

D.H.S.S. (1979) *Morbidity Statistics from General Practice 1971-72*, H.M.S.O., London.

D.H.S.S. (1982) *Steering Group on Health Services Information*, A report on the collection and use of information about hospital clinical activity in the N.H.S. H.M.S.O., London.

D.H.S.S. (1983) *Health Care and its Costs*, H.M.S.O., London.

Duncan, I.B. and Noble, B.M. (1979) The allocation of specialties to hospitals in a health district, *Journal of the Operational Research Society*, Vol. 30, pp. 953-964.

Feldstein, M.S. (1967) Economic analysis for health service efficiency. *Contributions to Economic Analysis*, 51, N. Holland, Amsterdam.

Forte, P. (1982) Costs and modelling in Health Services: a bibliography. Working Paper 337, School of Geography, University of Leeds.

Forte, P. and Wilson, A.G. (1983) Models of hospital costs. Working Paper, School of Geography, University of Leeds.

Gibbs, R.J. (1977) Health care resource allocation models - a critical review. RM-77-55, IIASA, Laxenburg, Austria.

Gibbs, R.J. (1978) The IIASA health care resource allocation model: Mk I. RM-78-8, IIASA, Laxenburg, Austria.

Hall, H.M. and Gibberd, R.W. (1982) Factors influencing hospitalization rates in the Lower Hunter region. Paper presented at ANZSERCH Conference, Christchurch, New Zealand, May 1982.

Hughes, D.J. (1978) The IIASA health care resource allocation sub-model Mark 2 - the allocation of many different resources. RM-78-50, IIASA, Laxenburg, Austria.

Leonardi, G. (1981) A unifying framework for public facility location problems part 1: a critical overview and some unsolved problems. *Environment and Planning, A*, pp. 1001-1028.

Mayhew, L.D. and Leonardi, G. (1981) Equity, efficiency and accessibility in urban and regional health care systems. W.P. 81-102, IIASA, Laxenburg, Austria.

Macdonald, A.G., Cuddeford, G.C. and Beale, E.M.L. (1974) Balance of care: some mathematical models of the N.H.S., *British Medical Bulletin*, 30, pp. 262-270.

McFadden, D., Cosslett, S., Duguay, G. and Jung, W. (1977) Demographic data for policy analysis. The Urban Travel Demand Forecasting Project, Phase 1, Final Report Series, Vol. 8, Institute of Transportation Studies, University of California, Berkeley, U.S.A.

Magee, C.C. and Osmolski, R. (1979) *Manual of Procedures for Specialty Costing*, University College, Cardiff.

Mooney, G.H. (1978) Planning for balance of care of the elderly, *Scottish Journal of Political Economy, 25*, pp. 149-165.

National Association of Health Authorities News. July, 1983, No. 63, Birmingham.

O.P.C.S. (1978) *Population Projections 1976-2016*, H.M.S.O., London.

Riley, M. (1982) Accessibility to hospitals: a practical application. *Environment and Planning, A, 14*, pp. 1107-1111.

Shigan, E.N. (Ed.) (1978) Systems modelling in health care: proceedings of an IIASA Conference, 1977. C.P. 78-12, IIASA, Laxenburg, Austria.

Townsend, P. and Davidson, N. (1982) *Inequalities in Health: The Black Report*, Penguin BOoks, Hardmonsworth.

Williams, H.C.W.L. and Clarke, M. (1983) *Micro-Analysis and Simulation in Urban and Regional Analysis* (forthcoming)

Wilson, A.G. (1981) *Geography and the Environment. Systems Analytical Methods*. John Wiley, Chichester.

Wilson, A.G. (1983) A generalised and unified approach to the modelling of service-supply structures. Working Paper 352, School of Geography, University of Leeds.

Wilson, A.G. and Clarke, M. (1982) Frameworks for modelling in relation to strategic planning in a health service. Working Paper 334, School of Geography, University of Leeds.

Wilson, A.G., Coelho, J.D., Macgill, S.M. and Williams, H.C.W.L. (1981) *Optimization in Locational and Transport Analysis*, John Wiley, Chichester.

ALLOCATION OF	TO	SPATIAL/ UNIT SCALE	TEMPORAL SCALE	EXAMPLE	REFERENCE (eg.)
RESOURCES	REGIONS (R.H.A.)	NATIONAL→ REGIONAL	ANNUAL	R.A.W.P.	D.H.S.S.(1976)
RESOURCES	FORMS OF TREATMENT/ SPECIALITIES	ADMIN. UNIT/ HOSPITAL	ANNUAL	D.R.A.M.	HUGHES & WIERZBIAN(1980)
PHYSICAL INFRASTRUCTURE (Hospitals, Ambulance Stations)	LOCATIONS	ADMIN. UNIT	STRATEGIC	LOCATION/ ALLOCATION	MAYHEW & LEONARDI(1981)
GROUPS OF PATIENTS	ALTERNATIVE TYPES OF SERVICE	ADMIN. UNIT	ANNUAL	BALANCE OF CARE MODELS	McDONALD, A.G., CUDDEFORD & BEALE (1974)
INDIVIDUALS	CARE TYPES	ADMIN./ HOSPITAL UNIT	ANNUAL	LIST PROCESSING	CLARKE & PRENTICE(1981)
GROUPS OF PATIENTS BY LOCATION	HOSPITALS	ADMIN. UNIT	ANNUAL	SPATIAL INTERACTION MODELS	RILEY (1981)
COSTS	SPECIALITIES	HOSPITAL	ANNUAL	STATISTICAL ESTIMATION	ASHFORD *et al.* (1981)

Table 1: <u>Examples of different types of allocation problems in health services research</u>

Households in previous list	Label	Age Cohort	Age	Sex	Marital Status	Race	Education Status	Occupation Class	Wks worked Previous Year	Annual Wage	Wage Trajectory	Full time Part time
1	1058.1	4	30	Male	Divorced	1	3	11	52	5110.11	1.4	1
2	2069.1	2	21	Male	Single	1	2	19	0	0	0	0
3	2187.1	3	25	Male	Married	1	4	16	52	4842.06	1.27	1
	2187.2	2	23	Female	Married	1	4	3	52	3635.18	1.11	1
4	2206.1	8	54	Male	Married	1	4	3	52	8914.73	1.25	1
	2206.2	9	55	Female	Married	1	2	3	52	7567.65	1.05	1
	2206.3	3	28	Female	Single	1	2	21	52	0.0	0	0
	2206.4	4	33	Male	Single	1	2	16	52	4069.8	0.98	1
	2206.5	1	20	Male	Single	1	2	21	0	0	0	0
5	2728.1	7	46	Male	Married	1	4	11	52	3461.27	0.91	1
	2728.2	6	41	Female	Married	1	2	18	52	4225.86	1.24	1
	2728.3	2	21	Female	Single	1	2	6	52	3875.89	1.22	1
6	3031.1	11	69	Male	Married	1	4	20	0	0.0	0	0
	3031.2	10	60	Female	Married	1	4	21	0	0.0	0	0
7	3039.1	7	46	Male	Married	1	2	14	52	6804.96	1.34	1
	3039.2	6	42	Female	Married	1	3	7	52	5142.55	1.28	1
	3039.3	1	12	Female	Single	1	1	0	0	0.0	0	0
8	4092.1	6	44	Male	Divorced	1	3	9	52	7495	1.33	1
9	4107.1	4	34	Female	Divorced	2	4	20	0	0	0	0
	4107.2	1	7	Male	Single	2	1	0	0	0	0	0
10	4521.1	7	45	Male	Married	1	3	15	52	3693	0.91	1
	4521.2	6	42	Female	Married	1	3	20	-	-	-	-
	4521.3	1	11	Female	Single	1	1	0	-	-	-	-
	4521.4	1	7	Female	Single	1	1	0	-	-	-	-

Table 2 : Example of micro-level specification.

TABLE 3 INITIAL POPULATION ATTRIBUTES AND CLASSIFICATION

Household Attributes	Classification
Label	
Sex of head	Male, female
Marital status of head	Single, married, widowed, divorced
Household size	1 - 10
Number of children	1 - 8
Tenure	Owner/occupier, public sector rented, private rented
Location	24 Kirklees wards
Socio-economic group of head	I - IV
Household income	Sum of individuals' income plus benefits

Individual Attributes	Classification
Label	
Age	Absolute age
Age cohort	15 age cohorts
Sex	Male, female
Marital status	Single, married, widowed, divorced
Country of birth	UK, Irish Republic, 'India', Pakistan, Carribean, Rest of World
Occupation	1 - 18 occupation groups, unemployed not in labour force, retired
Education status	I - IV based on age at leaving full-time education (15, 16, 18, 21+)
Annual income	Derived from wage model based on age, occupation, sex

TABLE 4 AGE AND SEX DISTRIBUTION FOR KIRKLEES 1981 : OBSERVED AND PREDICTED

		0-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75 +
Males	Actual	32.04	7.34	7.04	7.86	6.56	5.96	5.47	5.57	5.82	4.90	4.42	3.44	3.56
	Model	30.47	6.80	6.62	7.91	6.70	6.64	5.88	6.03	5.62	5.16	4.42	3.20	4.55
Females	Actual	28.44	6.84	6.39	7.40	5.99	5.43	5.09	5.38	5.60	5.14	5.29	4.83	7.68
	Model	27.57	7.46	6.65	7.74	6.27	5.68	5.22	5.53	4.94	5.28	5.11	4.18	8.37

N = 13,000

TABLE 5 TENURE DISTRIBUTION KIRKLEES 1981 : OBSERVED AND PREDICTED

	Observed	Model
Owner Occupier	63.96	63.72
Council Rented	26.23	26.33
Other	9.81	9.95

N = 13,000

TABLE 6 DISTRIBUTION OF POPULATION BETWEEN CENSUS WARDS, KIRKLEES 1981 : OBSERVED AND PREDICTED

Zone	Actual	Model
1	4.41	4.33
2	4.25	4.23
3	4.57	4.42
4	3.66	3.42
5	3.32	3.47
6	3.44	3.37
7	3.76	3.80
8	4.46	4.59
9	4.74	4.99
10	5.18	4.82
11	4.60	4.25
12	3.33	3.03
13	2.94	2.70
14	4.91	4.79
15	5.09	5.08
16	3.77	3.83
17	5.40	5.62
18	3.50	3.82
19	2.35	2.56
20	3.64	3.82
21	4.29	4.42
22	3.60	3.61
23	5.74	5.84
24	5.03	5.19

N = 13,000

1. Infective and parasitic diseases
2. Neoplasms (malignant)
3. Neoplasms of lymphatic and maematopoietic tissues
4. Benign neoplasms
5. Endocrine, nutritional and metabolic diseases
6. Diseases of blood and blood-forming organs
7. Mental disorders
8. Diseases of nervous system
9. Diseases of eye
10. Diseases of ear and mastoid processes
11. Rheumatic fever, hypertensive disease and heart disease
12. Diseases of peripheral circulatory system
13. Diseases of respiratory system
14. Diseases of digestive system
15. Diseases of urinary system
16. Male genital disorders
17. Diseases of breast and female genital system
18. Conditions of pregnancy, childbirth and puerperium
19. Diseases of skin and subcutaneous tissue
20. Diseases of musculoskeletal system and connective tissue
21. Congenital anomalies
22. Certain causes of perinatal morbidity
23. Symptoms and ill-defined conditions
24. Fractures, dislocations and sprains
25. Other injuries and reactions
26. Persons without current complaint or sickness

Table 7: Diagnostic Conditions (I.C.D. Classification)

INPATIENT DEMAND BY CONDITIONS

MALES

CONDITION	0-1	2-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+	TOTALS
1	20	20	20	30	30	10	0	0	0	0	132
2	10	0	0	0	0	30	30	0	10	20	101
3	0	0	0	0	0	0	0	0	0	0	0
4	0	10	0	0	10	30	0	10	0	0	61
5	10	0	0	0	10	10	0	10	30	10	81
6	0	10	0	0	0	30	0	20	0	0	61
7	0	30	20	41	20	10	30	20	0	20	193
8	0	0	20	20	10	0	20	0	0	10	81
9	0	20	10	30	10	10	20	10	20	20	152
10	0	10	0	10	0	0	0	0	0	0	20
11	0	0	0	10	30	10	112	112	101	122	497
12	0	0	20	20	0	20	51	81	20	71	284
13	41	91	101	61	51	71	41	61	61	20	593
14	20	51	112	142	173	101	71	71	0	51	792
15	0	0	20	10	0	51	0	20	41	20	162
16	20	30	10	20	0	10	10	20	10	0	132
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	10	0	20	41	41	10	10	0	10	142
20	0	0	0	61	41	81	61	112	20	41	416
21	10	0	20	10	10	0	0	10	0	0	61
22	254	0	0	0	0	0	0	0	0	0	254
23	30	20	112	51	71	~~61~~	51	51	20	30	538
24	0	20	20	20	0	10	0	0	20	0	91
25	10	10	51	142	152	91	10	91	10	0	568
26	10	0	0	10	0	20	10	0	0	0	51

TABLE 8(a).

FEMALES

CONDITION	0-1	2-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+	TOTALS
1	20	51	30	10	10	20	20	20	10	10	203
2	0	0	0	10	51	41	41	41	20	41	244
3	0	0	0	0	0	0	0	0	0	10	10
4	0	10	0	10	20	61	20	10	10	10	152
5	10	0	0	10	30	0	10	30	0	10	101
6	0	10	0	30	30	0	71	41	41	51	274
7	10	10	10	20	71	0	41	0	30	30	223
8	10	20	0	10	0	10	20	10	10	10	101
9	10	20	0	0	10	20	10	0	0	20	91
10	0	10	10	0	0	0	0	0	0	0	20
11	0	0	0	10	0	0	30	61	91	244	436
12	10	0	10	20	71	61	10	30	71	152	436
13	20	41	51	30	20	51	20	101	51	91	477
14	41	20	30	61	152	112	101	41	30	61	649
15	10	20	0	0	10	20	30	20	10	20	142
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	20	274	213	173	142	142	10	10	984
18	0	0	0	101	81	41	0	0	0	0	223
19	10	0	10	41	10	20	10	10	41	20	173
20	0	0	0	51	61	91	112	71	71	81	539
21	10	0	0	10	0	0	0	0	0	0	20
22	304	0	0	0	0	0	0	0	0	0	304
23	20	30	51	71	112	101	71	30	10	81	589
24	0	0	0	0	0	0	0	10	30	61	122
25	0	30	81	152	51	61	61	20	10	91	558
26	0	10	0	51	30	41	10	0	0	0	142

TABLE 8(b).

SPECIALTY BY CONDITION

SPECIALTY

CONDITION	1	2	3	4	5	6	7	8	9	10	11
1	101	132	0	0	61	0	0	10	10	20	0
2	51	10	0	20	213	0	0	0	51	0	0
3	0	0	0	0	0	0	10	0	0	0	0
4	0	0	0	0	152	0	20	0	41	0	0
5	61	20	0	30	30	0	10	0	20	0	10
6	122	20	0	41	91	0	0	0	61	0	0
7	233	61	0	81	10	0	10	0	0	0	20
8	71	51	0	20	0	0	41	0	0	0	0
9	0	0	0	0	0	0	0	244	0	0	0
10	10	30	0	0	0	0	0	0	0	0	0
11	426	0	0	233	0	0	0	0	0	0	274
12	183	20	0	213	254	20	0	10	10	0	10
13	507	355	0	122	10	71	0	0	0	0	10
14	81	30	0	20	1248	0	0	0	41	0	20
15	10	30	0	0	233	0	0	0	30	0	0
16	0	0	0	0	132	0	0	0	0	0	0
17	0	0	0	0	183	0	0	0	802	0	0
18	0	0	0	0	0	0	0	0	223	0	0
19	0	10	142	0	61	0	101	0	0	0	0
20	10	0	0	91	10	0	842	0	0	0	0
21	0	0	0	0	41	0	20	0	0	20	0
22	0	41	0	0	0	0	0	0	0	518	0
23	162	61	0	10	680	0	30	20	112	30	20
24	0	0	0	0	0	0	213	0	0	0	0
25	375	41	10	10	375	30	203	71	10	0	0
26	0	20	0	0	30	0	10	0	132	0	0
TOTALS	2405	934	152	893	3816	122	1512	355	1542	589	365

SPECIALTIES

1 GENERAL MEDICINE
2 PAEDIATRICS
3 DERMATOLOGY
4 GERIATRICS
5 GENERAL SURGERY
6 EAR NOSE & THROAT
7 ORTHOPAEDIC SURGERY
8 OPTHALMOLOGY
9 GYNAECOLOGY
10 SPECIAL CARE
11 CORONARY CARE

TABLE 9.

OPERATIONS BY SPECIALTY

OPERATION	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0	0	0	41	0	0	0	0
2	0	0	0	0	20	0	0	0	0	0	0
3	0	0	0	0	0	0	0	254	0	0	0
4	0	0	0	0	0	122	0	0	0	0	0
5	0	0	0	0	10	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	112	0	0	0	0	0	0
8	20	0	0	0	1116	0	0	0	71	0	0
9	0	0	0	0	213	0	0	0	71	0	0
10	0	0	0	0	213	0	0	0	0	0	0
11	0	0	0	0	41	0	0	0	964	0	0
12	0	0	0	0	10	0	0	0	284	0	0
13	0	0	0	0	10	0	741	0	0	0	0
14	0	0	0	0	122	0	0	0	0	0	0
15	0	0	0	0	20	0	132	0	0	0	0
16	30	10	0	0	183	0	10	0	0	0	0
17	0	0	0	0	51	0	203	0	61	0	0
TOTALS	51	10	0	0	2121	122	1126	254	1451	0	0

TABLE 10.

SURGICAL OPERATIONS

1 NERVOUS SYSTEM
2 ENDOCRINE SYSTEM
3 EYE
4 EAR NOSE AND THROAT
5 UPPER ALIMENTARY TRACT
6 THORAX (WITH HEART & LUNGS)
7 BREAST
8 ABDOMEN
9 URINARY SYSTEM
10 MALE GENITAL ORGANS
11 FEMALE GENITAL ORGANS
12 OBSTETRICS
13 ORTHOPAEDIC
14 PERIPHERAL VESSELS
15 SKIN & SUBCUTANEOUS TISSUE
16 OTHER SURGICAL PROCEDURES
17 NON-OPERATIVE PROCEDURES

SPECIALTY	HOSPITAL 1	2	3	4	5	6
1	1111.1	1241.9	0.0	0.0	0.0	0.0
2	0.0	425.2	0.0	0.0	0.0	0.0
3	158.8	0.0	0.0	0.0	0.0	0.0
4	0.0	924.4	60.6	0.0	526.5	185.0
5	521.0	1071.5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	31.5	0.0	0.0
7	0.0	0.0	123.4	1652.1	0.0	0.0
8	102.7	0.0	0.0	0.0	0.0	0.0
9	185.9	430.2	0.0	0.0	0.0	0.0
10	0.0	290.2	0.0	0.0	0.0	0.0
11	0.0	242.5	0.0	0.0	0.0	0.0
TOTALS	2079.5	4625.9	183.9	1683.7	526.5	185.0

TABLE 11 : Cost by hospital and specialty (£000's) (excluding obstetrics)

COST BY AGEGROUP, SEX & SPECIALTY

MALES

SPECIALTY	0-1	2-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
1	0.0	0.0	1.3	266.1	100.0	110.4	63.7	179.9	430.7	175.1
2	63.9	108.6	59.9	10.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	3.9	8.4	41.3	16.1	24.5	0.0	9.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	42.7	321.8
5	10.7	13.6	41.3	105.7	106.1	139.4	38.5	123.5	34.0	94.6
6	0.0	0.0	3.8	5.7	1.0	4.8	0.0	0.0	0.0	0.0
7	0.0	36.2	31.7	53.1	46.9	77.8	99.1	158.9	85.6	63.6
8	0.0	2.2	1.1	7.1	4.9	16.5	4.9	5.5	9.3	14.3
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	216.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	27.4	9.1	49.7	26.4	30.4	0.0
TOTALS	290.8	160.5	139.1	451.8	294.6	399.3	272.1	550.7	632.9	678.4

TOTAL COST FOR MALES 3870.1

FEMALES

SPECIALTY	0-1	2-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
1	0.0	0.0	0.0	42.9	49.4	93.3	125.6	207.8	92.1	414.6
2	41.6	75.1	66.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	5.2	0.0	7.1	0.0	0.0	13.6	0.0	0.0	4.5	25.2
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	194.2	148.8	956.9
5	4.3	13.5	25.9	121.9	153.2	119.0	107.0	107.4	81.6	151.3
6	0.0	0.0	1.0	0.0	3.8	7.6	0.0	3.8	0.0	0.0
7	0.0	8.0	0.7	43.7	49.5	69.7	86.3	128.3	217.2	519.3
8	1.6	2.2	0.0	0.0	0.5	4.4	3.8	0.0	0.0	24.2
9	0.0	0.0	3.0	222.2	130.8	119.3	52.3	57.8	13.5	17.2
10	74.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	7.1	5.1	11.2	47.7	10.1	18.3	0.0
TOTALS	126.8	98.7	103.7	437.8	392.4	438.1	422.8	709.5	576.1	2108.6

TOTAL COST FOR FEMALES 5414.4

TABLE 12 : Cost by age, sex and specialty (£000's) (excluding obstetrics)

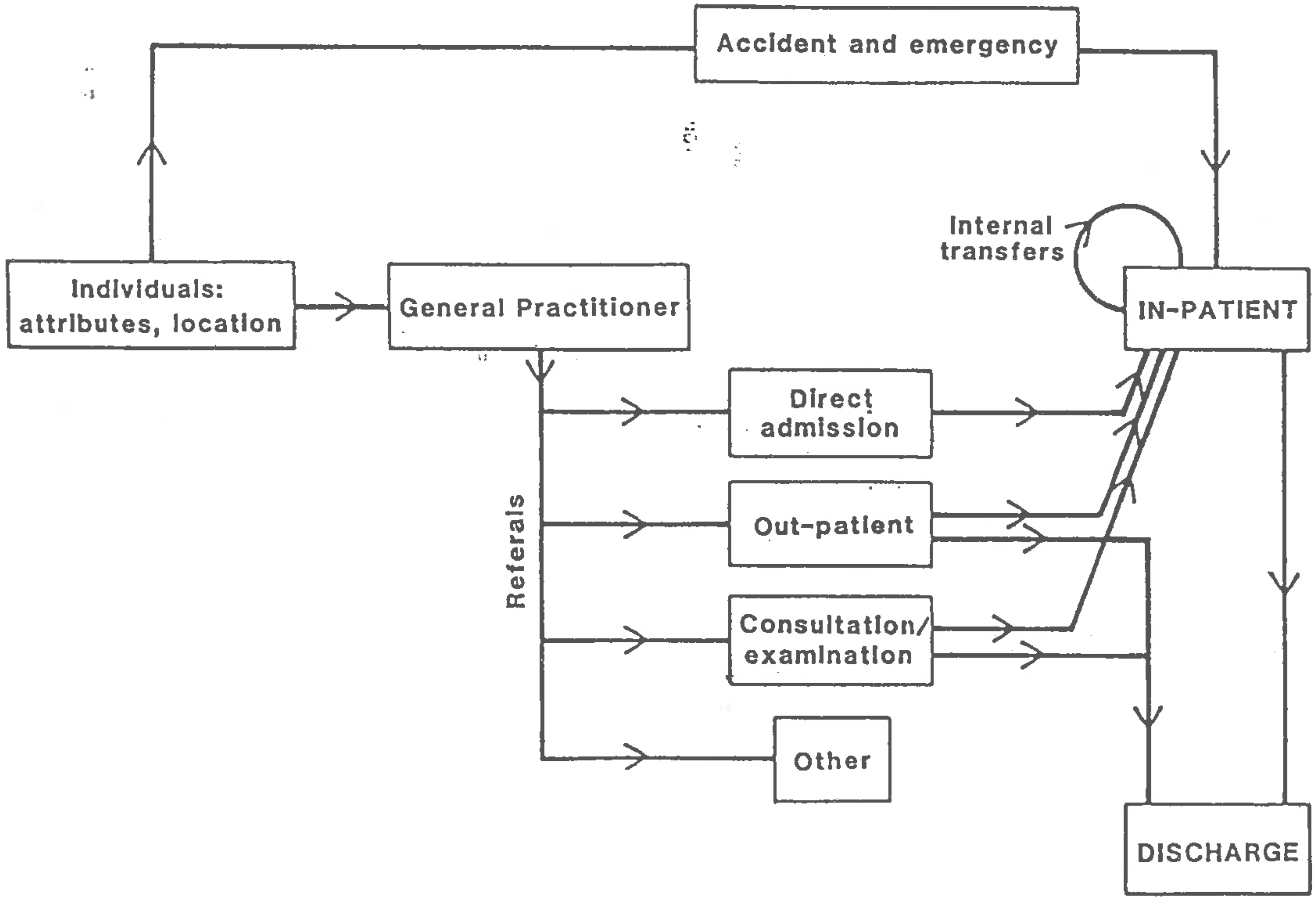

Figure 2 : Examples of flows in the patient-hospital interface.

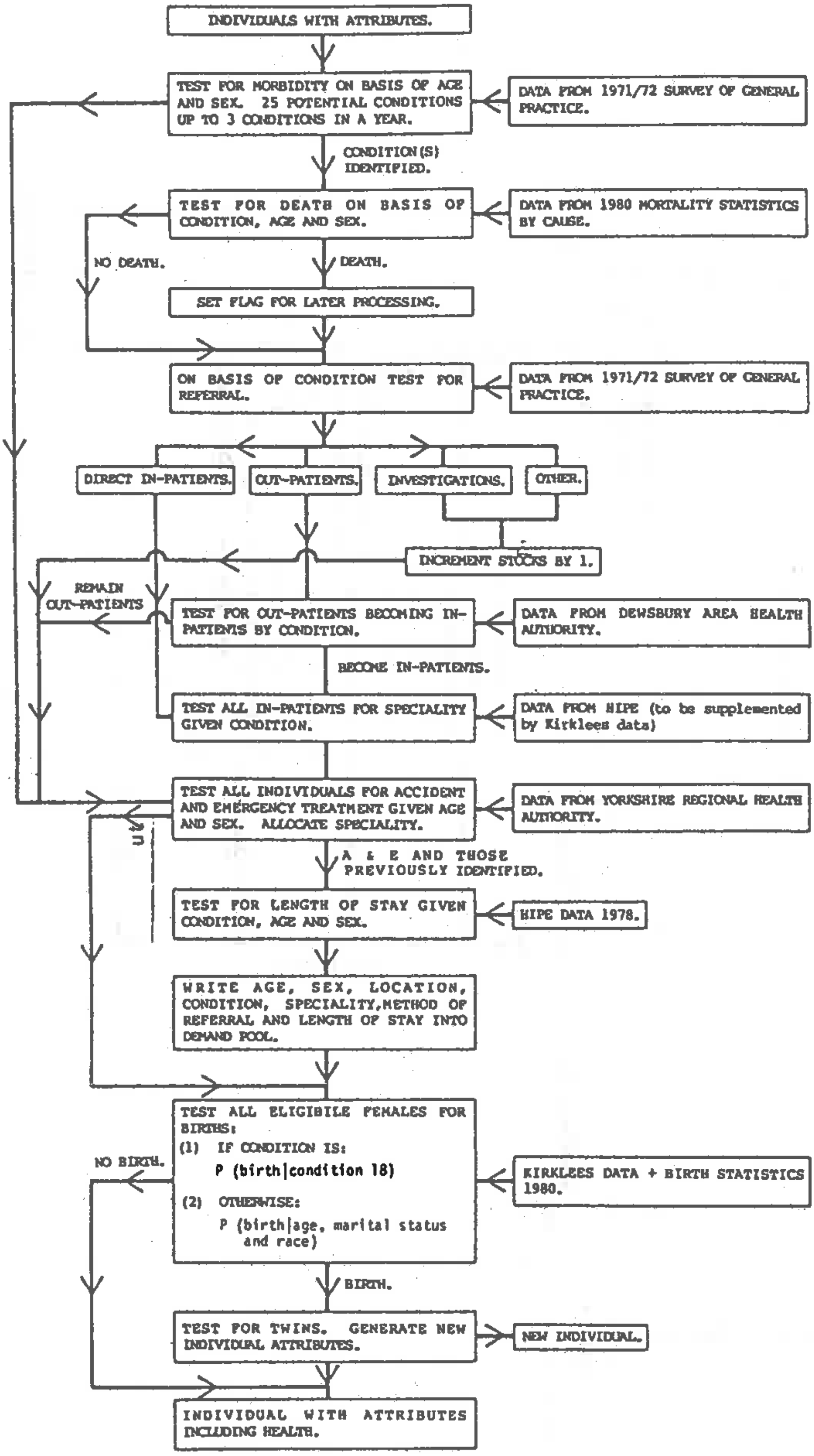

Figure 3 : Morbidity Model

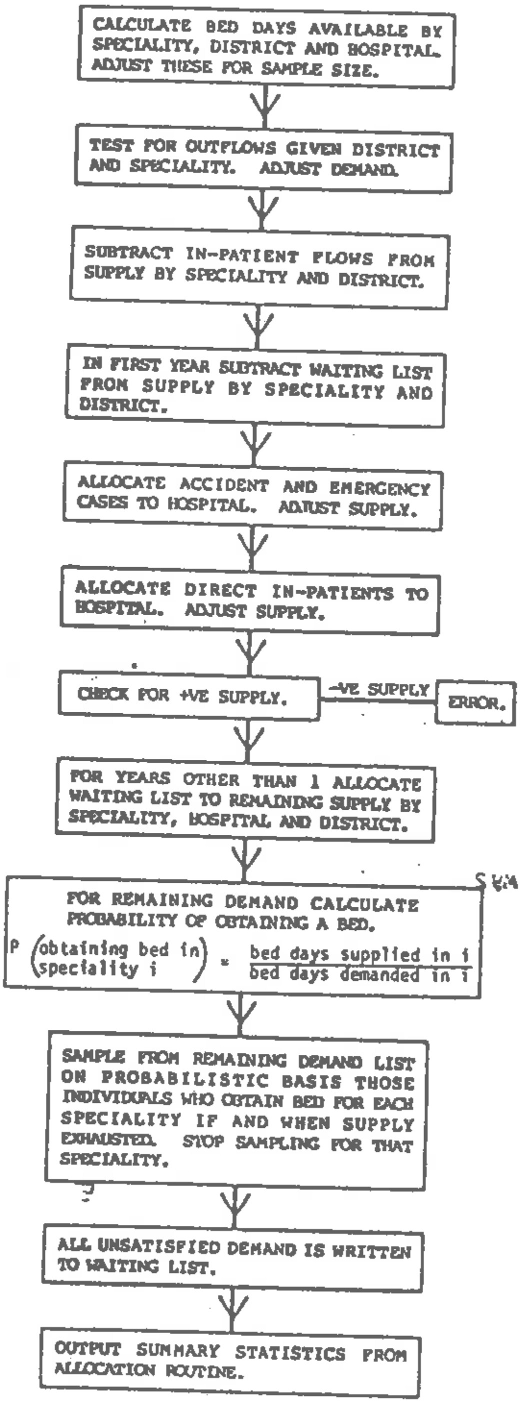

Figure 4 : ALLOCATION MODEL

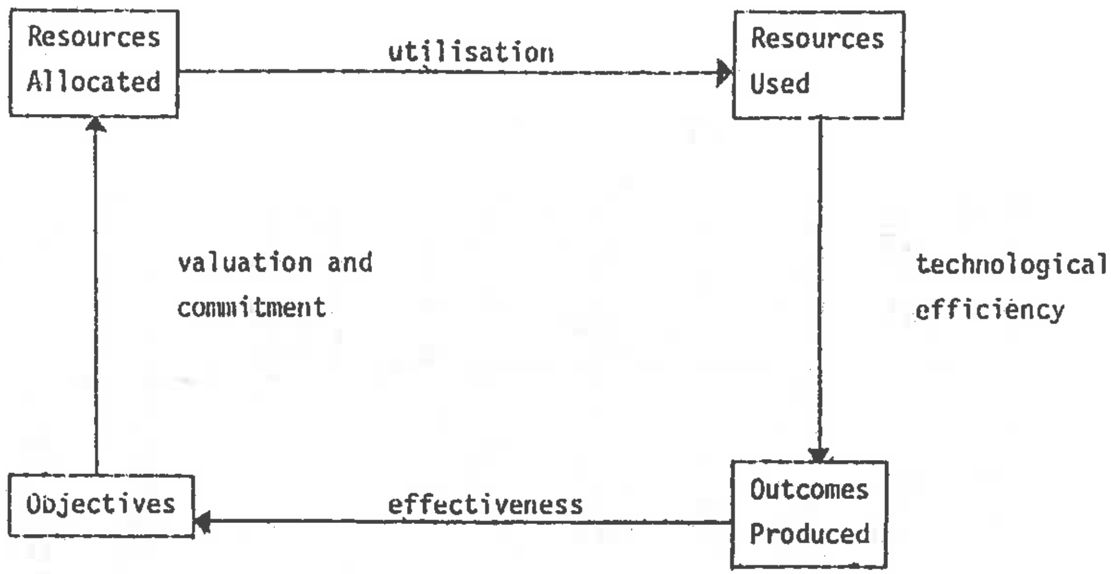

Figure 5 : A planning framework