VANCOUVER REGIONAL HEALTH PLANNING MODEL

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Summary

An aggregate simulation model of the health care system existing in Vancouver, Canada has been created as part of a multi-purpose regional simulation project. The model requires data on population trends, morbidity, health resource trends. Under a variety of possible policies (ZPG, for example) the effects in terms of surpluses and shortages of resources, untreated cases, and a scale of social impact attributable to Holmes are delineated over a n-year horizon. The results are intended to provide policy-makers with contingency forecasts for priority assignment, resource formation, and demand-resource matching.

Introduction

Concern over the manner in which health care is delivered in Canada has led to the construction of a simulation model of the health care system existing in Vancouver, Canada. It serves as one module of a larger simulation project, the Inter-Institutional Policy Simulator (IIPS). This simulator of the Greater Vancouver region combines modules for a variety of different and important aspects of activity in the region: pollution, human-ecology, population, transportation, land use, and several others.

Most modeling efforts today in the simulation of health care are concerned with sub-processes and system components.[3,8,14] Such simulations deal, for example, with one hospital department or with one function such as admission or referral. However, there have recently been efforts to model aspects of the health care system on a more aggregative scale such as in the community health care delivery model of Kennedy[10,11] and the Markovian model of Navarro et.al.[12]

Our model differs from previous models in several ways. First, the Canadian environment places constraints on organizational structures and policies which are markedly different from those found in the U.S. system. Secondly, since this model is imbedded in a larger modeling effort, explicit provision can be made for changes in future governmental resource allocation on the basis of current health care indicators. A third is that there are implications of our simulation method for health care measurement, since we give explicit consideration to medical and socio-economic criteria in health care planning of policies for priority assignment, resource formation and demand-resource matching. The model provides contingency forecasts for the policy-maker of demands the system will have to meet, the resources made available to meet these demands, the shortages resulting, and measures of the social impact of these shortages.

Vancouver Regional Health Planning Model

Purposes

The Regional Health Planning Model is a macro-management model intended to aid in policy formulation and in resource allocation in the Greater Vancouver Regional Model. The overall model is an ongoing effort of the Inter-Institutional Policy Simulation Project as a cooperative effort of the City of Vancouver, the Greater Vancouver Regional Board of Planning, the University of British

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*The technical assistance of Ron Strohmaier and Ian Banks is appreciated.
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Columbia and the Ford Foundation. A five-year commitment exists to develop a model on which a variety of policies may be tested in a simulated world so that the unexpected and deleterious consequences of these policies might be ascertained *ex ante*. Representatives of possible users, then, are involved in model creation.

The decision on how to partition the urban system into subsystems for simulation purposes was an important one. Typically, a practical criterion is that each subsystem should concern an aspect which merits study in its own right and which is not cross-connected to the other subsystems through such a dense network of variables as to render the idea of separation meaningless. There is always the danger that the very selection of such subsystems could force not only the modeling, but also the policy proposals and the solutions ultimately adopted into certain preset modes. If this happens, then one expressed purpose of the modeling, that of being able to propose and test radically new solutions, could be prevented *ab initio*, that is, such modeling would necessarily be a failure by restricting the conception of the system and its testing to limited and probably unsatisfactory ways.

In the present study this problem is well illustrated by the health care system. Thus we do not consider the subsystem of medicine alone, as implemented through hospitals, physicians' practices, and pharmacies. Rather we consider the health care system with its implied attention to various preventative measures for maintaining well human beings.[4] Implied is the concept that some performance measures must be sought so that the cost-effectiveness levels of systems with greatly different priorities in policy can at the least be qualitatively ordered with some confidence.

Assumptions

This section will now briefly explain the major assumptions made in the model.

Health Care Assumptions. A systems analysis of the health care system requires the existence of a measure of effectiveness by which different alternatives can be compared. At the present time there is no generally acceptable measure. Within this study, ordinal measures of priority for health service and ordinal measures of perceived seriousness of illness, both by physicians and by consumers are used as effectiveness criteria. While these techniques require further refinement, they can already aid in the identification of important policy areas.

The demands made on the health care system to some extent depend on the level of awareness of the public. For instance, a health education campaign may make consumers more aware of the need for periodic examinations for cancer and heart disease and thus increase the *observed* incidence rate for these conditions. In general, health education campaigns may make consumers more aware of diseases, increase their perception of problems, enhance their evaluation of their health state, and increase their propensity to seek health care when they perceive the need to act. The incidence rates used in this model are current incidence rates which can be altered by various interventions such as the health education campaign. The technical quagmire of the determination of basal levels for the existence of disease, a task of monumental proportions that no government has yet undertaken, is thus avoided.

Population Assumptions. Population figures by age and sex are determined from regional census data of 1966 adjusted by prevailing death, birth, and mobility rates. No attempt is made to adjust these figures for socio-economic class or other variables.

Morbidity Incidence Assumptions. U.S. data adjusted by local data reported for British Columbia on morbidity by disease, age and sex were used as surrogates for data for the Greater Vancouver Region. Discussion of the appropriateness of U.S. incidence rate data in this model is complicated by the fact that significant waiting periods in excess of several months exist for many non-emergent conditions in British Columbia. This backlog of untreated cases would distort data collection efforts on incidence rates. However, strategies for further data collection are being considered.

Environmental Assumptions. As they do in the real world, various environmental factors can influence the incidence rates in this model. Factors were chosen for inclusion in the model because of their importance, the ability to correlate these factors with changes in incidence rates, and the fact that many represent anticipated interactions with other modules of the Vancouver Regional Planning Model. These are air pollution (particulate and gaseous), water quality, accidents, crowding, nutrition, and noise level. Other factors could be included as information becomes available.

Health Care Delivery Assumptions. Assignment of resources for the treatment of patients in given disease classes was calculated through evaluation of expected lengths of stay in hospitals, physician visits, nursing time, etc.

A priority system has been included in this model. It reflects the saturation of provincial health care services in British Columbia which has forced *de facto* schemes for priority servicing. This is further reinforced by delays, especially at the primary care level, before an initial visit to the physician can be arranged when the reported medical condition is minor in nature.

A six-point scale for priorities has been constructed. This is developed from a "seriousness of illness rating scale" (SIRS) which has been created by Holmes and his colleagues,[21] providing ordinal and cardinal rankings for the seriousness of 126 diseases with seriousness rated from 21 to a maximum of 1160. These rankings were prepared both by physicians and by consumers with a high degree of concordance between the groups. Transforming these ratings from the SIRS scale to our aggregated six-point scale results in a more tractable priority system from the programming standpoint while retaining the conceptual essence of the ranking. The basic priority estimates for each illness on the six-point scale were adjusted by professional judgment to reflect its various degrees of seriousness. For example, heart disease and hypertension occur with varying levels of seriousness. Thus a discrete probability distribution can be constructed which defines the proportion of cases which fall into each priority level. In the example of heart disease and hypertension, 50% are taken to be of priority class 1, 20% each of classes 2 and 3, and 10% of class 4. For other aggregative disease categories, a weighted average of probability distributions for component diseases was computed. To the extent that illness seriousness ratings were not available, in some categories the probability distribution is an extrapolation from the distribution of seriousness of known component diseases.

The priorities for cases of untreated diseases in one period may be changed to expedite service in succeeding periods. Obviously, the failure to treat a disease in one period may have such consequences as death, disability, or spontaneous recovery, which in these cases reduce the need for service in succeeding periods. On the other hand, the failure to treat may increase the priority levels necessary in succeeding periods.

When a patient with a given disease and priority level cannot be treated in a given period by the obviously pertinent resources, the model allows resources to be substituted. In primary care, for instance, a case of influenza could be treated equally well by a pediatrician, an internist, or a general practitioner regardless of patient age or sex. Unfortunately, such rigidities as medical specialization and facility specialization may prevent substitution in other cases.

Model Structure

Overview. As previously stated, the Vancouver Regional Health Planning Model is intended to serve as an aid in policy formulation and in resource allocation in the Greater Vancouver Region.

The model has been constructed and programmed in such a manner that it can operate with different degrees of detail. For example, the time unit initially chosen is a year. This is the time frame amenable to current practices of centralized health care decision-making in the region (for example, capital budgeting for the health care system is done on a multiple-year basis). If this time unit should change, it would only involve parametric changes in the program. The practicality of the model is enhanced by the organization of British Columbia's health care. Currently long-range planning and capital budgeting in British Columbia are undertaken by hospital districts. These hospital districts, while of varying size, nevertheless provide most inpatient services for a large geographic area. The Greater Vancouver Hospital District encompasses more than 75% of the area modeled by this simulation. Planning and budgeting responsibility are delegated to the districts by the provincial government which funds operational and capital expenses in hospitals under a province-wide scheme. The geographical responsibility of the districts reduces the managerial and analytical concern that would be present, for instance, under the U.S. system, on overlaps in patient flow, hospital competition, redundant services, hospital service areas, etc.

The present model is concerned primarily with the provision of health care. While environmental and social impact are expressed through adjustment of incidence rates for medical conditions, it is hoped to broaden this perspective to provide greater emphasis on the ecological perspective of health promotion as opposed to the prevention and care concepts emphasized in the current model.

In structure the model is comprised of four major processes: disease generation, priority streaming, allocation of resources and evaluation of system shortages. It is an iterative resource allocation model, running over multiple periods, with carryover of unsatisfied demand, when applicable, to succeeding periods. System shortages and idle resources have policy feedback implications, the determination of which must await the construction of other modules of the Greater Vancouver Model. For instance, the existence of job-seeking psychiatric nurses in excess of system requirements (a current Vancouver problem) should provide an impetus within the model for policy changes. Examples are; reduced government expenditures on basic education for psychiatric nurses, expanding the domain of their responsibilities or limiting the inflow of trained psychiatric nurses into British Columbia.

Major Subroutines

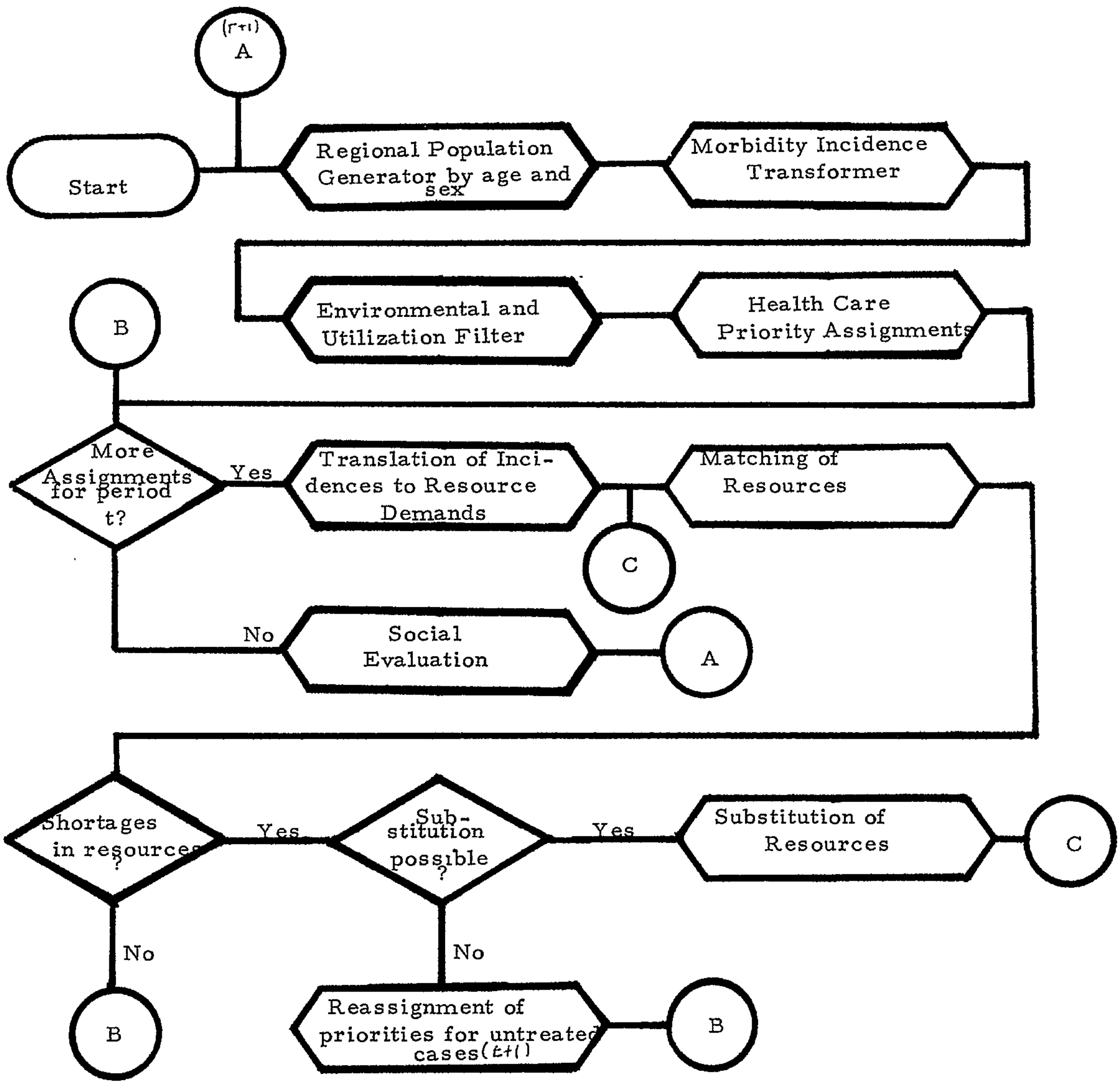
The major subroutines are listed below.

a) Morbidity Generation. Adequate data on disease rates have been found. Census figures classified by age and sex, but not by socioeconomic condition, have been provided by the Population Module of the IIPS model and have been adjusted for the Greater Vancouver area. Incidence rates have been inferred from U.S. data on over 280 diseases or disease groups comprising a large majority of disease classes by the International Classification of Disease and comprising most frequently reported medical conditions in in hospital inpatient, hospital outpatient, and private practice settings.[1,6] This data has been aggregated into 24 disease classes and by age and sex.

The combination of population class data and incident rate data enable "crude" estimates to be made of the numbers of people in the Greater Vancouver area with diseases in these disease classes. The estimates are crude in the sense that they reflect recently reported incidence rates by age and by sex. Feedback from other groups such as Environment, Pollution, Education can alter these rates. For instance, a campaign undertaken to reduce air pollution should affect the incidence of respiratory diseases.

Utilization of the health care system by the individual is dependent on a chain of factors. (Figure 1) The individual must first perceive the existence of a possible disease and weigh its perceived seriousness and his perceived susceptibility. His decision to seek treatment may be limited by the local availability of health care services under acceptable financial, socio-legal, and time-consumption conditions. In British

Figure 1. Health Care Flow Chart



Columbia, all health care services, excluding dental services and cosmetic surgery, are available at nominal cost due to universal health insurance. While this removes one barrier, insufficient health facilities result in long waiting lists and delays for many elective services.

In the absence of other modules providing these policy feedbacks and estimates of their effect on incidence rates, the crude incidence rates are also the final incidence rates.

b) Priority Streaming. In a situation where scarcity of resources exists, it is necessary to apply some priority scheme to insure that needs are filled according to their urgency. Thus as already noted, each disease category is allocated a probability histogram of six basic priority levels according to professional panel judgments about current practices. For patients who do not receive treatment in one time period, however, a new priority may be assigned for the succeeding time period. This is of course exemplified by the patient for elective surgery, as opposed to the accident victim who is always treated as an emergency in the current time period.

c) Allocation of Resources. There are 11 classifications of resources: 9 physician types, beds, and nurses. Estimates of resource requirements have been made for the disease classes. Available resources are matched with patients in disease classes in order of the disease class priority ranking until all classes are examined. Where shortages in resources exist, two routes are possible: if substitution of alternative resources is allowable this is done. For instance, there is no question that a child with an upper respiratory condition can be treated easily by a general practitioner, an internist, or a pediatrician. In such a case, a change is made in the resource requirements for people in the given disease class and matching is again attempted. If substitution is not possible, a higher priority, where applicable, is reassigned for the succeeding time period. Information concerning the unsatisfied demand is retained for computation of social benefits in the current period and as an added disease class (with its associated priority making it uniquely different from the same disease class at its crude incidence rate) in the succeeding period. When all classes have been examined, evaluation of system shortages for that period are computed and either another period can be simulated or the simulation run can be stopped (Figure 1).

d) Evaluation of System Performance. It is impossible to construct a satisfactory performance index or objective function for a health system at this time.[4,7] The many problems include:

(i) The outputs which are meaningful in an optimization sense are mostly unmeasurable, even if they can be conceptually defined. Thus while the number of days in hospital, and the resulting costs, for patients with a given illness can be measured, these figures bear no necessary relation to the amount of benefit received by the patients or by society.

(ii) In the absence of ability to measure outputs, the inputs, namely, the prevalence figures for the illnesses, may be used as proxies. Clearly such a circularity carries the danger of completely useless analyses.

(iii) As already noted, the public expenditures which bear upon the health care system may be divided into three major sectors, which may be broadly defined as "public works", "education", and "medical care". If the outputs are restricted to those discussed in (i) and (ii), that is those pertinent to the medical care sector only, then at best any optimization attempted can only be that of a subsystem.

Consequently we propose to investigate performance with at least some weighting given to the improvement of socio-psychological well being achieved by the system. The shortages in the health care system could be perceived as obvious and relatively immediate indicators of unsatisfactory performance. These could well be fed back very effectively through the political process at the appropriate regional level.

A relatively new approach to the quantitative description of illnesses offers some promise in the weighting of shortage costs and in obtaining an indicator of their possible political impact. Thus, as already noted, Holmes and his colleagues[21] have constructed a quantitative scale for rating the seriousness of the most common and representative illnesses. This Seriousness of Illness Rating Scale (SIRS) has been shown by them to have both satisfactory reproducibility[22] and agreement between the scaling by medical and non-medical people. It is based on personal perception of an illness's seriousness, given just one normalizing value, which was specified as 500 for Peptic Ulcer. The scale then ranges from Dandruff as least serious (rank 1) with a score of 21, through Common Cold (rank 8, score 62) to Heart Attack (120, 855) and Leukemia (126, 1160). Perceived seriousness therefore varies by a factor of 50, and seems a good candidate as a sensitive measure of social concern with illnesses.

Inasmuch as the penalty of not treating such illnesses as cancer (125, 1020), in the given period would typically be perceived as being much greater than that of not treating illnesses such as varicose veins (39, 173) in the same period, it may be necessary to assign a further weighting factor defining the need for immediate treatment. Note that this same aspect has been dealt with in determining the range of priorities, out of the ordinal range available (1-6), accorded to aggregated illness groups in allocation of resources in this model.

Presumably maximum benefit is not realized from the system unless demands as weighted by the seriousness scale and the promptness of treatment, are minimized. Thus, viewed the other way round, the achieved benefits can be measured as the summation of patient inflow rates, suitably weighted by the SIRS scale and by the promptness of treatment.

The existence of the illness seriousness scale enables the model to operate either in terms of the preferences established by physicians or those established by consumers. In the current model, the priority streaming is dependent on the medical preferences whereas the evaluation of social impact is evaluated on the preferences of the non-medical group.

We should also note that many illnesses are known to be psychosomatically related to stress level, for example High Blood Pressure (91, 520), Peptic Ulcer (89, 500), Migraine (56, 242) and Eczema (45, 204). Indeed Holmes and his colleagues[9] have established a quantitative scale for the perceived seriousness of various "life events" (similar to SIRS), such that by accumulating these "Life Change Units" over a period of time (typically two years) a probability of illness onset can be assigned for the next short period (typically six months). From such work there begins to emerge an exciting conjecture that aggregation and individual health may serve as a causally-meaningful indicator for social health or vice versa. That is, the quality of life in the larger social system of which this HCS is a part depends on the health of individuals as much as on the health level of society. Hence in our subsystem an adequate performance measure must ultimately be able to incorporate the decrease of illness prevalence rates as a "good". Thus the optimum in achieved benefits would be partially dependent on maintaining the lowest possible prevalence rates channeled through the hospital-medical care system. This would have obvious cost-benefit considerations.

e) Model Outputs. In order to permit the user to utilize the program, a number of outputs are provided:

(i) Yearly output: The first item produced for each year is a listing of the data inputs: population, incidence rates, resource availabilities, etc. This is followed by a policy-intervention vector which delineates the various changes in parameters that have been incorporated for the current year and subsequent years. System performance for the current year is summarized and tabulated in terms of treated and untreated cases by disease class. Further policy information is provided through an inventory of resources utilized, idle resources, and shortages.

(ii) Run summary output: Similar data are provided for the entire period over which the model is run.

While this information is currently available only in tabular form, a command language is under development to allow on-line graphical display of this model's output as well as that of the total regional simulator.

Data Requirements

In a simulation of this kind it is especially important to define the proper data space. It was possible to select the appropriate exogenous variable and parameter data from available statistical data banks or to adopt existing data for the modelling purposes. While we were able to rely mainly on B.C. statistics, it was necessary to modify by local data and conditions the U.S. data on demands on physician time and on incidence rates in order to execute the model with experimentally valid inputs. A brief description of the major data collection problems and our attempts at resolution follows:

Demands on Physician Time. Of the data pertaining to the 16 specialties categorized in Specialty Profile[16] (accounting for approximately 90% of physicians with a private practice), all but that relative to the Psychiatrist/Neurologist was used. We felt that, at this time, the project could not easily handle the psychiatric and neurological conditions.

In order to be compatible with available data on medical manpower in the lower mainland and greater Vancouver regions of British Columbia, it was necessary to aggregate various specialties as shown below:

(i) General practitioner includes dermatologist, allergist, and osteopathic physician.

(ii) Internal medicine includes gastroenterologist, proctologist and cardiologist.

The relevant data given for each speciality were the number of specialists, reason for visit, and number of visits for a specified reason. Multiplying the number of visits by the number of physicians active in a speciality gave the number of visits by speciality for a specified reason. This figure was then converted to visits/100 population. The number of visits available per year for each specialty, at the work load level of the survey summarized in Specialty Profile (1968) was calculated as follows:

daily patient load* x number of specialists** x 220

The data for physician load were adjusted by figures of sampled physician loads in the relevant regions of B.C. published by the British Columbia Health Resources Council.[13]

Incidence Rates. Incidence rates of acute conditions were obtained from the National Center for Health Statistics (NCHS) (1967), where the data were given by broad categories of diagnosis/100 persons/year, by age and sex.

* Based on a five-day week.

** In the lower mainland and greater Vancouver regions - source 13.

Incidence rates of chronic conditions were obtained from NCHS[6]. It was necessary to transform the incidence rates to "per 100 persons" in a given age and sex classification. Rates of incidence for both chronic and acute conditions were adjusted to B.C. conditions by a factor computed on the basis of mortality and survival rate ratios for both the U.S. and British Columbia and rates available for reportable diseases in B.C. In order that the various data be compatible, it was necessary to aggregate them into broad diagnostic categories, and from the data on incidence and visits, it was then possible to compute the number of visits/incidence by diagnosis and specialty.

Bed Requirements. From the rate of hospitalization/100,000 population, average length of stay and the incidence rate/100 population (U.S. data), the number of bed days/incident for the various aggregated categories of diagnosis were derived on the basis of British Columbia statistics[17]. From data published in the Report on Hospital Statistics and Administration of the Hospital Act, B.C.[13] the number of bed days available/year was calculated by multiplying the rated bed capacity of hospitals in the lower mainland and greater Vancouver region by the number of days/year.

Graduate Nurses. From the same report, the number of full-time equivalent graduate nurses working in hospitals in the region was obtained. Based on the number of nurses working/day, the number of nurses/bed day was calculated, as well as the yearly available graduate nurse/bed/days. The number of registered nurses working in B.C. in 1970 was obtained from the Registered Nurses Association of B.C.

Other Considerations. Various service visits to physicians, e.g. checkups, innoculations, and several diagnoses for which incidence data was not available were handled in a slightly different manner.

In order to utilize the simulation program and data relevant to the above cases the incidence/100 population was replaced by total visits/100 population and the visits/incident was set equal to the fraction of visits seen by a specialty. Disease categories 24-27 are medical service disciplines and not incidences.

Project Resources

Computer Resources. The program consists of about 700 statements in four sets of subroutines. These were written in FORTRAN IV largely out of programming, compilation and operational convenience and because of the extensive amount of data refinement. Data improvement will eventually be required for regional population generation, morbidity incidence transformation and environmental and health services interventions. Another reason for the use of FORTRAN IV was the convenient matrix programming possible for the priority streaming routine. A further technical reason for the use of the language chosen lies in the very nature of the simulation. This simulation has an input-output structure rather than the process flow structures for which languages such as GPSS or SIMSCRIPT 1.5 would have been appropriate. Compilation time is approximately 40 seconds with execution time of from 5 to 25 seconds.

While the current version of the model will run on any computer with FORTRAN IV capability, the plans for later data management, interaction, and data display necessitate the use of a large-scale computer system with on-line capabilities. The University of British Columbia's 360/67 fully duplexed system provides this necessary environment.

Manpower Resources. Because the Vancouver Regional Health Care Planning Model is one of the subsystems in the overall Vancouver Regional Planning Model, we have access to the resources of other associated groups. For example, the Population subroutine was developed in cooperation with the Population Group. Data for environmental impact were provided by the Pollution, Transportation and Human Ecology Groups. The data management problems associated with input, output, and interaction on an on-line basis are being resolved with the assistance of the Data Management Group. The various groups consist of over 50 active participants drawn from the Vancouver municipal government, the Greater Vancouver Regional District Board, faculty members from the University of British Columbia, and other potential users.

The Health Systems Group itself consists of 12 active members, with specialities including epidemiology, bio-statistics, biomedical engineering, economics, operations research, and information systems.

Model Realism

The Vancouver Regional Health Model is intended to serve a prescriptive role in aiding in policy decisions. It does not purport to be a descriptor of current modes of health care delivery in the Vancouver area. There are several major differences.

One of the primary ones is our assumptions of substitutability of resources. Whereas one disease may be treated by several physician types, a patient is more likely to remain with his personal physician until he is free to provide service. This introduces one form of rigidity in the real-life situation. By the same token there are questions of hospital staff privileges that reduce the accessibility of health resources.

A second difference is the masking effect of current backlogs for health care in Vancouver. Without extensive and expensive survey-sampling techniques, there is no way to determine which part of present demand is attributable to past shortages of resources. Without such data at some point in time for initialization, historical validation would be irrelevant even if our model were descriptive in nature.

A third difference, and perhaps the most important, is an attempt to use a rational priority scheme in order to determine who gets served and who waits. For the most part, this decision is presently in actual use for small segments of consumers in need of health service. Examples include emergency rooms and committees for renal disease patients. It would be too idealistic to expect a completely acceptable, completely rational priority scheme in health. Yet, in the face of current and impending shortages, the rise of suboptimal or ad hoc schemes to determine priority could be predicted in the absence of a more complete scheme of priorities.

Experiments

So far, we have only run some pilot tests to illustrate the nature of our experimental design. Two population policies were considered: the first was zero population growth (ZPG), permitting families to have a maximum of two children. The second population policy could be considered as normal population growth characterized by a mild exponential increase. The ZPG policy is of ecological current interest, while the second policy represents existing demographic trends.

The four basic resource formation policies considered were: (i) equal size yearly increments to health care resource levels amounting to 1% of the initial resources, (ii) compound increases of 1% in resource availabilities, (iii) equal size increments amounting to 2% of the initial resources, and (iv) compound increases of 2%.

Long lead times in the construction of health facilities and in the implementation of medical education programs require the advance planning of resource formation. The resource policies tested represent two basic alternative planning methods which can "bracket" uncertain estimates of population growth; these are constant yearly increments and exponential increases of resource levels. The experiments provide information on resource utilization and shortages caused by the configuration of population and resource policies and they point to more refined resource allocation patterns.

Experiments i - iv. Normal population growth with the four resource growth policies (i - iv) was tested over a number of simulated years. In year one, the regional population amounted to 1,116,703 growing to a population of 2,109,793 in the fifteenth year. It was assumed that migration patterns did not change, i.e. the same relative proportions were maintained. The fact that the geographical area of the study was not limited to the city boundaries, but consisted of a broadly defined metropolitan area, contributes to the realism of this assumption.

In this experiment the morbidity composition did not alter significantly during the span of the experiment. However, the number of cases did increase significantly, as one would expect. For example, upper respiratory conditions (diagnostic group no. 2) rose from 323,638 in the first year to 532,842 episodes in the fifteenth year, a 65% increase. Similarly, heart conditions and hypertension increased over the same period from 6,605 to 11,762 episodes, a 78% increase. Overall, a slight change in composition of morbidity becomes apparent, representing a shift from acute to chronic conditions. This is explained by a higher median age of the population in the last periods,which cause an increase in chronic and other degenerative conditions which are primarily age-dependent problems.

These trends in the episodes of disease resulted in a significant impact on the performance of the health care delivery system. Table 1 summarizes the extent of those resource shortages appearing in relevant years.

It appears from the table that the general practitioner (category no. 1) is underutilized through about year 15 for all four strategies and iii and iv thereafter. However, excess demands for other specialties are filled by the general practitioner and, in fact, cause full utilization of his services. In the experiment we have allowed for substitution between the various medical disciplines as well as some substitution, on the basis of prevailing customs, between hospital beds and physician time. Consequently, shortages resulting in untreated episodes are experienced by the system under the various resource strategies between the 5th and 10th years. Figure 2 illustrates the social impact of shortages for the respective policies.

As noted in the description of the model, the social impact figures should be interpreted as qualitative indicators of public dissatisfaction resulting from untreated episodes. The indicators reflect the weights assigned by the public showing the perceived seriousness of the episodes. It should be noted that while policy (iv) appears to be the more satisfactory in terms of public reaction, it creates more short-term surpluses in the availability of physician time. However, this surplus may not necessarily become apparent since in such conditions the physicians could influence the demands on their time by tending to provide higher service rates per episode. (The averages for this region are already higher than in the U.S.; experimental runs with U.S. averages for the resource mix per episode indicates that B.C. has significant disguised idleness of health care resources. There is no evidence, however, that the quality of health care is significantly higher in B.C.)

In conclusion it seems that strategies which create slight shortages in the short run and avoid long-run shortages, will maintain the system's efficiency with no significant negative social impact.

Table 1

Surpluses and Shortages of Resources
and Social Impact

(Yearly Visits and Bed/Days Both in Thousands)

	Selected Years																	
	1	5					10					15					23	30
Strategy	all	(i)	(ii)	(iii)	(iv)	(v)	(i)	(ii)	(iii)	(iv)	(v)	(i)	(ii)	(iii)	(iv)	(v)	(v)	(v)
Population	1,116,703	1,335,660				1,114,256	1,674,993				1,182,741	2,109,793				1,228,027	1,304,183	1,351,604
Physician Visits																		
1	1505	1209	1221	1366	1375	1461	681	695	1034	1092	1382	-58	-2	491	646	1283	1124	1033
2	-320	-450	-450	-433	-432	-338	-657	-660	-618	-611	-363	-929	-925	-868	-838	-393	-445	-476
3	148	115	115	131	132	143	58	59	95	101	135	-21	-17	37	53	126	110	109
4	-38	-68	-67	-62	-61	-42	-68	-14	-102	-99	-48	-176	-175	-156	-151	-55	-66	-73
5	-112	-178	-178	-169	-164	-118	-288	-286	-259	-254	-130	-436	-433	-391	-379	-147	-175	-191
6	71	40	41	52	53	66	-11	-10	15	19	58	-80	-77	-40	-29	50	35	26
7	-51	-91	-91	-83	-83	-56	-157	-156	-139	-136	-64	-244	-242	-216	-208	-74	-91	-101
8	-22	-38	-38	-29	-29	-12	-104	-103	-84	-81	-26	-194	-192	-164	-155	-43	-54	-51
9	15	5	5	8	8	13	-12	-12	-5	-4	10	-35	-34	-24	-20	8	3	-1
Bed days	23	-113	-113	-66	-63	29	-391	-386	-284	-267	-10	-772	-761	-607	-560	-59	-121	-143
Nurse Hours	1061	1075	1076	1127	1130	1061	1071	1076	1188	1207	1054	1046	1058	1227	1279	1045	1031	1027
Social Impact Index of Untreated Cases $x10^{-6}$	0	0	0	0	0	0	3.93	3.92	2.47	2.30	0	19.27	19.08	11.20	10.35	0	.027	1.88
Untreated Classes	none	none	none	none	none	none	11,14 17-22 24,26 27	11,14 17-22 24,26 27	17-22 24,26 27	18-22 24,26 27	none	2-6, 8,9, 11,12 14-22 24,26 27	2-6, 8,9 11,12 14-22 24,26 27	2,3, 11,14 17-22 24,26 27	2,3, 11, 17-22 24,26 27	none	27	17-22 24,26 27

(i) normal population growth with 1% linear resource growth (ii) normal population with 1% compound resource growth (iii) normal population growth with 2% linear resource growth (iv) normal population growth with 2% compound research growth (v) zero population growth (ZPG) with no resource growth.

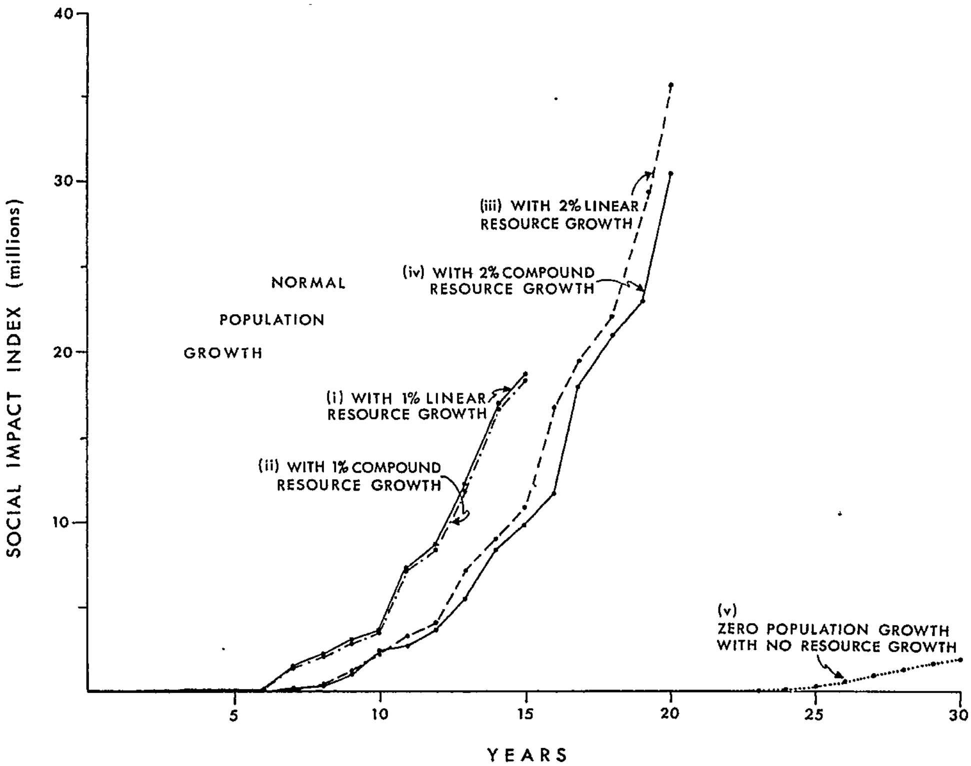


Figure 2 Evaluation of Shortages for Resource Policies

Experiment v. This experiment investigates the performance of the Health Care System under approximately "zero-population growth," with no resource growth (Strategy v). Population does increase, however, through net migration. The size of the population varies from a total of 1,118,583 in the first year to 1,228,027 in the 15th simulated year. Results are shown under (v) in Table 1. Because of the change in the age structure the system shifts in emphasis from acute to chronic diseases. For example, a sharp decrease in the number of episodes in infective and parasitic diseases is accompanied by an increase in the number of episodes of heart condition and hypertension, arthritis and rheumatism.

In terms of the resource requirements, the immediate reduction of births leads to a decrease in required obstetrician visits, as well as to a decrease in required hospital beds. Bed/day idleness rates reach their peak in the third year and the excess capacity decreases into the 23rd year due to changes in the morbidity structure. After the 23rd year the system will experience bed shortages.

The surplus of total physician time (if substitution between specialties is permitted to eliminate shortages in a particular discipline) decreases gradually through about the 10th simulated year and decreases more rapidly thereafter through the 23rd year when a slight shortage begins to occur. By year 30, substantial shortages exist, although as Table 1 shows, the social impact index for ZPG in that year is lower than for any of the tested normal population growth strategies in year 5. The mix of medical specialties will need to change in order to meet these shifts in morbidity patterns.

The change in the rate of decrease of surplus physician resources is evident when the number of women of childbearing age increases during the following years. The phenomenon, combined with the shift in the age structure, explains the eventual increase in required resources. One must note that, in the long run, the impact of ZPG in alleviating shortages of health care resources will be substantially reduced if changes in medical technology increase the expected life-span of the population.

Extensions

Four extensions are currently being designed. The first includes changes in resource mix, especially those which concern the delegation of physician tasks to nurses, and those prescribed for the treatment of some conditions.[19] A second extension is to consider the environmental impact on health care demands, e.g. changes in transportation patterns that alter accident rates or health education campaigns that alter perceptions.

A completely different benefit-imputation scheme is presently under consideration employing concepts advanced by a branch of the U.S. government[4]. In the absence of a better measure of health levels, it is possible to construct an ordinal preference scheme based upon the degree to which failure to treat a given condition will result in the restriction of ability to perform normal functions. These are given below in order of decreasing severity:

death
inability to perform one's major activity
restriction in performance of a major activity
inability to perform a minor activity
discomfort
no restrictions or discomfort

The associated definitions are painstakingly defined for the U.S. National Health Survey. Briefly, a major activity would be one's job if one works, housework if one is a housewife, school if one is a student. A minor activity would be a recreational activity, a hobby, or similar activities. While these definitions have sprung primarily from definitions for chronic conditions, they apply equally well to acute conditions and injuries in this application to the evaluation of untreated cases. For instance, an untreated bee sting may cause a day of discomfort but no other harm. Failure to treat influenza may force one to stay in bed for two added days making it impossible to perform one's major activity during that time.

Through an experienced panel of physicians with expertise appropriate to given disease classes, estimates of functional restrictions as a result of failure to treat could be made in a manner analogous to the determination of expected length of stay. Thus, for a given vector of untreated cases, with up to 24 components, we could obtain a social dysfunction vector with six elements for which we have an elemental ordinal preference scheme. With only six elements the exclusion of dominated alternatives is somewhat simplified and further choices by the appropriate decision-maker greatly simplified. In addition, the sensitivity of the optimal solution to alternative benefit schemes could be explored.

A final extension under consideration is the coupling of this simulation to a hospital management game. Economic cost:effectiveness information derived from an extension to this simulation could be used to help formulate the rules of the game. By the same token behavioral patterns discovered in the playing the game, for example, reaction to incentive reimbursement schemes, may be correlated with the cost:effectiveness results of their associated resource allocation patterns.

Conclusions

This health care model, as demonstrated by initial runs, provides a means of examining the effects of changes in population, morbidity and available resources when measured against a social impact scale based on seriousness of illness. Effects of policy changes can be traced over a number of simulated years in terms of this scale and in terms of shortages or surpluses of resources.

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