# A Comparative Analysis of Hospital Supply Planning Models

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I am indebted to my parents for their constant encouragement and support throughout my university life.

For whatever errors of fact or reasoning which remain within the study, I am solely responsible.

Denis J. Roch

ABSTRACT

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In this study an attempt was made to select an appropriate hospital supply planning model for Manitoba. Upon selection of a model, estimates of future demand for hospital facilities were made for the years 1976 and 1981.

Selection of the model required an analysis of previous methods used for planning purposes. Properties of each model were examined so as to extract the advantages and disadvantages inherent in their structure. Thus by illustrating the variability in the conclusions resulting from the adoption of conventional techniques a model was chosen which did not suffer from the shortcomings of other planning models. The model chosen however, was not the one which the previous analysis indicates as to being the best. Such factors as time and cost constraints involved, precluded the use of the best method. Thus in a sense, the model which was used is the "best" considering the financial resources available. Having chosen the model linear regression analysis was used to empirically fit the data to the model. After estimating the coefficients of the model projections of future

hospital utilization were made for 1976 and 1981.

In general, the conclusions drawn from the analysis indicated that the present hospital facilities could accommodate the population of Manitoba until 1976. However new hospital facilities would have to be built for 1981 considering the expected increase in patient admissions at that time and if no other methods of delivery of health care are implemented. Considering the high cost of this method of medical treatment (i.e. hospitalization) alternatives could be found which are less costly. Thus if such alternatives as ambulatory care centres were implemented which could act as a substitute to hospital care then it may not be necessary to build new hospital facilities for 1981. This tentative conclusion rests on the assumption that alternative methods of delivering health care can act as a substitute to a hospital. If this is so these alternatives could decrease hospital utilization rates.

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# CHAPTER ONE

## INTRODUCTION

The application of economic analysis to the allocation of public expenditures is rapidly gaining recognition. This is especially so in important sections of the economy such as the health care "industry". Compared to other industrial sectors of the economy it is much less exposed to market forces and competitive pressures which act as incentives to efficiency. The private sector which operates on the tenents of profit maximinization achieves economy of resource utilization by the elimination of high cost producers by those more efficient. Among hospitals however, this competitive process operates under very severe contrainst if at all. A patient or doctor cannot select on the basis of cost any hospital he wishes, a patient has to be hospitalized where his physician is affiliated. The implementation of comprehensive insurance programs which ensures hospitals of financial support further decreases the degree of cost competitiveness in this sector. These characteristics may thus account for this sectors lack of incentives to achieve efficiency.

The lack of economic decision making as well as the expansion of services provided has resulted in ever-increasing costs of health services. In 1955, total health care expenditures per capita in Canada were about $60.00 in current dollars.[1] This figure had risen to almost $170.00 by 1967, and by conservative estimates is expected to slightly more than double to $345.00 per capita by the year 1975. A better indicator of rising health care costs is the cost of a hospital patient-day. This cost (expressed in current dollars) has risen in a public hospital from an average of about $5.00 in 1946 to about $50.00 in 1968. In 1970 some costs have been quoted to be as high as $70.00 per diem. Since the early 50's, expenditures on health care by all levels of government have expanded at a phenomenal rate of 14 percent a year reaching a level of $3.5 billion by 1969.[7] The Sixth Annual Review of the Economic Council of Canada further estimated that the rate of growth between 1967 and 1975 would be at a rate of over 9 percent a year in terms of constant dollars. This rate of growth is the fastest of any major category of government spending.

A further indication of the ever-increasing importance of health care expenditures is the share of Gross National Product alloted to this sector. In the mid - 1950's total expenditures on personal health care accounted for 3 percent of Gross National Product as compared to 5.5 percent in 1969. Estimates of the Economic Council of Canada[2] indicate that this figure is expected to rise to 6.5 percent of Gross National Product in 1975.

As indicated earlier there are few incentives to economic efficiency in this sector. Administrative skills, mangerial efficiency and cost consciousness have not generally been supported by those who have direct and indirect control over health services, namely physicians. Doctors in general, have been more interested in answering the question: "Will treatment X improve the health of this patient more than any other available treatment"? Cost-benefit comparisons of the efficiency of alternative methods of care have not been sought by doctors, perhaps because they have usually viewed their problem as largely uncontrained by economic considerations.

This fact, plus the virtually universal accessibility of health services in Canada, primarily as the result of health insurance coverage, has resulted in a breakdown or weakening of the "pricing mechanism" which encourages the economic use of resources. The result has been a sort of cost-plus system, biased towards health care in hospitals. Little has been done in the area of developing adequate but less costly alternatives outside of hospitals for less intensive kinds of care.

If we wish to reduce the cost of resourses allocated to the health-care industry then it is necessary to achieve more economical care through a more effective use of health care resources. To achieve this, health care authorities should strive for a socially optimal stock of hospital facilities. Through efficient use of resources and the maximization of some index of public health, health care authorities could determine the optical supply of hospital facilities.

However, the specification of a public health index[3] is extremely difficult if not impossible. The health of any nation's population is difficult to define or to measure with any degree of precision. The "output" of the health care "industry" as all other service industries has definite elusive quantitative, qualitative and price dimensions. Whenever one tries to measure intangible services, complex issues predominate. This is because the pattern of utilization of hospital facilities reflects a wide variety of influences other than those normally subsumed under the term "medical necessity". Whether a person is hospitalized or not depends upon his economic situation, the types of care available outside the hospital and the availability of a hospital bed, as well as upon the diagnosis. A patient may forego hospitalization depending upon his opportunity costs[4] and the presence of ambulatory care centres. The presence of alternative facilities may make it possible for medical doctors to consider the welfare of the "whole patient" and not merely his medical needs. These problems thus create serious actuarial definitional problems for planners seeking a measure of need for hospital facilities.

Thinking about these questions in terms of "needs" or "best possible care" is misleading. In selecting a method of care for a patient or a community, we cannot always opt for doing all that can possibly have useful effects. Namely, we do not push marginal productivity to zero. Because opportunity costs have to be considered, decisions to give more doctor hours, more nursing, or more bed-days to one patient, may deny these services to other patients. Decisions to allocate more money or buying drugs and equipment, attracting more nurses, building more hospitals, or increasing the stock of health care resources may imply a decision not to spend that part of the nation's total resources on education, housing, subsidizing corporations, defense Members' of Parliament salaries, etc. The selection of a particular level or method of health care is justified not because it is "necessary" or "good" use of resources but because it is an optimal use of these resources. Optimal in the sense that spending of a greater share of our national income on health would yield benefits which outweigh the losses caused by removing these resources from other use.

In decision-making, doctors and administrators should look for the "optimal" use of resources, by using some benefit-cost criterion of the efficiency of alternative methods of care and alternative programmes. An accurate optimal allocation of resources among the health services and among health and other wants of society may be impossible. However, thinking of the problem in terms of optimal allocation instead of the elusive concept of "meeting needs" should produce better decisions. Planning for an optimal allocation of health services would require considering the whole economic system whereas "meeting needs" results in piecemeal planning. Such economic decision-making would thus question the effectiveness with which such resources are being, or could be, used.

In so doing we will be able to estimate whether or not Manitoba has an optimal allocation of resources between health services and other wants of society. If it is found that undue pressure[5] is being exerted on the existing hospital facilities in Manitoba, then this will be an indication that spending of a greater share of our national income on health would yield benefits which outweigh the losses caused by removing these resources from other use. In other words we would be spending less than the optimal amount; conversely if we find that little pressure is being exerted on the existing facilities, then we are spending more than the optimal amount and should cut back expenditures.

In this study an attempt will be made in selecting the appropriate hospital supply planning model by illustrating the variability in the conclusions resulting from the adoption of conventional techniques. In Chapter 2, an examination of several supply-planning models will be undertaken. Properties of each model will be examined so as to extract the advantages and disadvantages inherent in their structure. In Chapter 3 we will investigate the influence of supply on the level of demand and we will try to determine whether supply creates demand or demand pressures influence the level of supply in the hospital system in Manitoba. Following this, in Chapter 4 a supply planning model will be developed which has desirable properties taking into consideration the given circumstances. In Chapter 5, we will fit empirically the model developed in the preceding chapter, with an analysis of expected future demands on the hospital system in Manitoba. In the last chapter a summary of the above analysis as well as the conclusions yielded by such an investigation will be put forth.

Footnotes:

1. Economic Council of Canada, "Patterns of Growth," Seventh Annual Review, September, 1970, p. 35.

2. ibid

3. The World Health Organization has yet to define a public health index.

4. Opportunity costs which include transportation costs, income foregone and all other costs to a patient during an episode of illness are the main private costs for residents of Manitoba.

5. Pressure is defined later on in Chapter 2.

# CHAPTER TWO

# ALTERNATIVE SUPPLY PLANNING METHODS

## 2.1 Introduction

In planning future hospital facilities in an area, two important problems must be investigated; first, an estimate has to be made of the future demand for hospital care and second, decisions have to be made concerning an optimal spatial distribution of hospitals within that area. In this chapter we will examine several methods of estimating the demand for hospital facilities. Each of the methods of measuring existing, and implied future bed requirements to be examined is operational, having been used in at least one hospital supply planning analysis. Through a critical examination of these methods we will try to determine the comparative suitability of each model in predicting future patterns of demand for hospital facilities in Manitoba.

## 2.2 Uniform bed-population ratio analysis

One of the initial attempts to relate the construction of hospital facilities to the requirements of a specific area and population to be served was based upon a uniform bed-population ratio. Such a study was the 1933 Lee-Jones report[1] on bed needs in the United States. This was one of the first studies to consider need in the sense of quality of care rather than existing patterns of use. Through an examination of data relating to morbidity trends, patterns of illness were translated into estimated bed needs. Outlines of "optimal care" for given diagnostic categories were established and related to projected estimates of incidence in order to estimate the total amount of care that was needed to reduce the incidence of disease of the population. These needed days of care were then translated into beds, assuming an 80% rate of occupancy. Using a population base of 100,000 the authors recommended that 4.62 beds per thousand population were needed.

This approach however, was criticized by the 1935 report of the American Hospital Association on Hospital Planning.[2] This committee questioned the validity of some of the generally accepted formulas used by previous study groups advocating uniform bed-population ratios. Examples of two of these morbidity "rules" are:

a) that 2 or 3% of the population will be ill at any given time and that 10% of these need hospitalization in acute beds.

b) that urban communities need 5 beds per 1000 population whereas rural communities needed one to three beds per 1000 population.

Applying these general rules to the urban population of Greater Winnipeg for 1968 the following acute care needs were predicted. (It is revealing to note the inherent contradictions in the predictions. The estimates were based upon the 1968 Metropolitan Winnipeg population of 523,000).

a) assuming that 2½% of the population are ill, this gives us (523,000 * .025) = 13,075 people who are ill.

b) 10% of these need hospitalization in acute beds. (13,075 * .10) = 1,308 people or 1308 * 1000/523,000 = 2.5 beds per thousand

c) Since this is an urban community the second rule states that 5.0 beds per thousand population are needed.

d) Thus for the community of Metropolitan Winnipeg, the first rule forecasts a need of 2.5 beds per 1000 population, while the second rule forecasts a need of 5.0 beds per 1000. Even if an arbitrary allowance of 1.0 beds per 1000 is included in order to oversupply to meet fluctuations in demand; if the estimates of demand reflect hospital bed needs, the ultimate implication is an overbuilding of hospital facilities.

This committee then presented new bed-population ratios based on the degree of urbanization. In their case the ratios reflected the fact that hospitals in rural had greater utilization rates[3] than hospitals in urban areas. Factors which may have led to greater use of hospital facilities in rural areas were:

a) the difficulty of getting to a hospital encourages the use of the hospital for preventive care in that some patients may be directed to the hospital prior to examination even though their admission is not warranted on medical grounds;

b) the relative shortage of doctors and long travelling distance may encourage doctors to hospitalize patients rather than make house calls which would entail what the doctor would feel was uneconomic use of a doctor's time

c) once the patients are in the hospital the length of stay may be longer to ensure that the physician does not have to make a house call and waste his valuable time travelling.

They suggested that these ratios should be used solely as guidelines, basing their reasoning on the observation that it is more economical for a hospital to be overcrowded for a few days every year rather than experience a bed surplus for the greatest proportion of the time. This method used probable utilization rates to measure bed needs rather than a more technical definition of need as used in the Lee-Jones report.

In estimating for need which reflects an arbitrary index of health care rather than a level of demand, problems arose:

1-) Morbidity data necessary to estimate need was lacking. Furthermore "need" has to be defined on some arbitrary index of health care.

2-) Building for an arbitrary level of need in advance of demand resulted in the past, in an overbuilding of facilities and a consequent under utilization of many facilities. This manifested itself in terms of longer than average duration of stays and low levels of occupancy for hospitals. (i.e. occupancy levels of less than 80% which is regarded as an acceptable level of occupancy by health authorities).

Furthermore the arbitrary presumption of a uniform bed-population ratio often will not reflect local conditions accurately.

Sizeable distortions can result when applying a uniform standard to a specific area. Two communities of identical population size will rarely demand the same number of beds. The reasons for the differences may be attributed to the following economic and socio-demographic variable: Economic level (income etc.), degree of industrial development, cultural characteristics, age distribution, climate, morbidity rate and the effectiveness of out-patient and home social welfare services. If it is obvious that the region lacks homogeneity, then the failure to incorporate the idiosyncracies of the population makes the application of a uniform bed-population ratio indefensible. Similarly, a bed-population ratio implicitly assumes that all beds are homogeneous with respect to the service provided and that all segments of the population are homogeneous with respect to the service required. In fact this is typically not true, rural beds in Manitoba are not used in the same manner as beds in Metropolitan Winnipeg. The relatively small size of the hospitals in the rural area as compared to those in Winnipeg indicates that for certain areas of treatment, hospital beds in rural Manitoba are not available. Thus patients needing a particular treatment may have to be referred to a large hospital in Winnipeg.

This leads us into another problem. The ratio is generally applied to a service area as if that geographical unit were a natural catchment area with no flow of patients into or out of it. As previously shown, in rural Manitoba certain illnesses cannot be effectively dealt with and have to be referred to Winnipeg. Thus a uniform ratio will tend to overlook such important planning factors.

In summary, the application of general rules which would strike an equilibrium between supply and demand for hospital facilities in a Metropolitan area results in an inconsistency as to what is the appropriate number of facilities required. One rule states 5.0 beds per 1000 and the other rule 2.5 beds per 1000 population. In view of the blatant inconsistencies as well as the arbitrariness of these decision rules and the criticism that a uniform measure is not applicable to all areas means that both rules must be discarded. Thus it seems reasonable to conclude that a uniform bed-population ratio is far from being the "optimal" criterion for estimating the demand for hospital facilities.

## 2.3 Bed-death ratio analysis

Another technique of estimating bed needs is the bed-death ratio. This ratio is based on the relationship between the predictability of death rates and an estimation of the proportion of deaths that will occur in the hospital. This method was first applied by the 1947 Commission on Hospital Care[4] in the United States.

According to its formulators this procedure has several distinct advantages. First, it places the emphasis entirely on need rather than on some combination of need and demand. The rationale of the technique is developed as follows: Most deaths are preceded by a certain amount of sickness; and each disease has an effect on mortality rates and life expectancy. Therefore, the number of deaths in an area may be used as an indication of the amount of hospital care or "need" required.

Secondly, it is based on vital statistics rather than just general population data. The contention is that there is an important relationship between mortality and the age distribution of the population which is very highly correlated with the crude death rate and, presumably, the sickness rate as well. The death rate thus measures two sources of variation in morbidity data: that due to the general health of the population, and that due to the age distribution of the population. Since the age distribution differs greatly from region to region, the death rate and, concomitantly, the probable level of sickness also varies from region to region.

Thirdly, it is worthwhile to allow differentials in the need for beds in different regions within a specified area. That is, the elements of the bed need formula should reflect the characteristics of the area in question.

For predictive purposes the bed-death ratio is easy to calculate because all that is required are two items of information; the projected death rates and the proportion of death that occur in the hospitals. The bed-death ratio and the resultant number of beds per 1000 population required can be calculated using the following formulas.

BDR = PD/(HD * 365 days)

where BDR = Bed-death ratio

PD = Patient-days per 1000 population

HD = Deaths per 1000 population occuring in the hospitals.

BN = (TD * H/R) * BDR

where BN = Beds needed per 1000 population

TD = Total number of deaths per 1000 population, (Includes out of hospital deaths.)

H = Actual percentage of deaths occuring in the hospitals.

R = Actual or desired % occupancy rate.

BDR = Bed-death ratio.

After calculating the beds needed per 1000 population (BN) a comparison can be made of estimated beds with existing number of beds. This method has been applied to Manitoba for the years 1962-68 and the results have been tabulated in the following tables. Table 2.1 shows the data used in calculating the bed-death ratio as well as the bed-death ratio for each year. Table 2.2 shows the estimated bed needs as well as the existing number of beds. The bed needs have been calculated for the proportion of deaths occuring in hospitals for each year as well as for the following proportion of deaths in each year; 80%, 90% and 100% of the deaths occuring in the hospitals.

In table 2.1 the bed-death ratio, for example in 1967 was calculated as follows.

BDR - 1559/(5.83 * 365) = .733

This bed-death ratio means that for each hospital death 0.733 beds are used for one year. The beds neededd per 1000 population is then calculated: (as in table 2.2 for 1967)

BN - (7.9 * 73.8/79) * .733 = 5.41

Table 2.1 Data for calculation of bed-death ratio in Manitoba for 1962-68.[5]

| Year | Death rate per 1000 population (TD) | % of deaths occuring in hospitals | Patient days per 1000 population (PD) | Death rate per 1000 population occuring in hospitals (HD) | % occupancy rate of hospital | BDR |
|---|---|---|---|---|---|---|
| 1962 | 8.0 | 72.3 | 1487 | 5.78 | 78.8 | .705 |
| 63 | 8.4 | 71.3 | 1522 | 5.99 | 81.1 | .696 |
| 64 | 8.1 | 73.6 | 1559 | 5.96 | 83.1 | .717 |
| 65 | 8.0 | 72.7 | 1560 | 5.82 | 81.3 | .734 |
| 66 | 8.2 | 73.3 | 1576 | 6.01 | 80.2 | .718 |
| 67 | 7.9 | 73.8 | 1559 | 5.83 | 79.0 | .733 |
| 68 | 8.1 | 73.5 | 1596 | 5.95 | 81.4 | .735 |

Table 2.2 Existing and estimated bed needs for Manitoba for 1962-68.

| Year | Existing beds per 1000 population | Beds needed at prevailing death occurences within hospitals | Beds needed with 80% of deaths in hospitals | Beds needed with 90% of deaths in hospitals | Beds needed with 100% deaths in hospitals |
|---|---|---|---|---|---|
| 1962 | 6.93 | 5.17 | 5.73 | 6.44 | 7.16 |
| 63 | 6.91 | 5.14 | 5.77 | 6.49 | 7.21 |
| 64 | 6.75 | 5.14 | 5.59 | 6.29 | 6.99 |
| 65 | 6.86 | 5.25 | 5.78 | 6.50 | 7.22 |
| 66 | 6.89 | 5.38 | 5.87 | 6.61 | 7.34 |
| 67 | 6.93 | 5.41 | 5.86 | 6.60 | 7.33 |
| 68 | 6.80 | 5.38 | 5.85 | 6.58 | 7.31 |

Examining table 2.2, we see that only if all deaths occur in the hospital, will the beds needed be larger than the already existing supply. Since not all deaths occur in the hospital it is safe to disregard this column. However, for all the other estimates it can easily be seen that the existing supply of hospital beds is greater than the bed needs in every year. Thus the bed-death ratio approach seems to indicate that the available number of beds in Manitoba for those years was more than adequate or else the method underestimates need.

However in spite of its' suggested merits, the technique has not been widely applied as an effective prediction model. It is an aggregate model and does not take into consideration age - specific death rates and no adjustments are made for probabilities of death occuring in hospitals on an age-specific basis. It also suffers from the same shortcomings of the uniform bed-population ratio in that it generalizes a uniform ratio across non-homogeneous segments of the population. Furthermore this approach like the previous ones, is circular - for example, bed needs are a function of the expectation of death in hospital...but the chances of death in hospital are influenced by the availability of beds. If there are few beds, only the very sick are admitted, and they are I suspect, more likely to die and thus raise the rate.

2.4 Queuing theory model

A queuing theory model for estimating the demand for hospital facilities was first developed N.T.J. Bailey and other researchers associated with the Nuffield Provincial Hospitals Trust. The theoretical framework, however, was first formulated by the Danish writer A. K. Erlang.[6] A queue (line) forms when the demand for a service becomes too great for the servicing capacity.

One of the first applications of the queueing theory technique was to a telephone exchange where only a fixed number of calls could take place at one time. Thus if there were more callers than the maximum a queue would form. Bailey felt there was a close analogy between this problem and between a hospital ward with a fixed number of beds. In both of these problems customers (patients) join a queue if there is no vacant facility when their demands arise. The use of a hospital bed is similar to the use of one of the channels and discharge from the hospital is similar to the completion of a call. The main assumptions behind this mathematical formulation are that demand arises at random and that discharges terminate at random.

The assumption of random demand, that inter-arrival times and services both follow the exponential distribution with a fixed mean not dependent on queue length nor varying with time seems reasonable. The fact that there may be seasonal fluctuations in some specialties is not too important if the time span is for a one year period. The other assumption, however, that patients recover at random, (i.e., bed occupancy times follow the exponential distribution with fixed mean,) was more open to question even if all illnesses are aggregated. Bailey once having examined hospital records, felt that many diagnostic categories seemed to have the general characteristics of the distribution.

The theory of queues is important for hospital administrators because waiting lines are commonplace in hospitals. These queues can create emotional hardships for the patient who in turn may transfer this frustration to the hospital officials. Administrators could then alleviate the source of the problem by using the mathematical theory of queues for waiting line planning purposes.

In order to gauge the actual demand in each diagnostic category for a group of hospitals Bailey analyzed their hospital records. From these he recorded admissions (or separations) and changes in the lengths of the waiting lists. He defined the number of beds which would supply exactly the amount of hospitalization demanded by the population of an area as the "critical number of beds". To this figure he added twice the appropriate standard error of estimate of the critical number plus one or two more beds to allow the waiting lists to decrease so that eventually the waiting lists will be reduced to a reasonable size. The critical number of beds would be calculated as follows:

$$\text{Critical number} = \left[(A + AW) / (365 * P)\right] * S$$

where

A = the number of hospital admissions (or separations) during the previous year.

AW= increase or decrease in the waiting list.

S= average length of stay in days.

P= proportional rate of occupancy of available beds.

If the average demand per day d = (A+AW)/ (365 * P) is estimated from a sample of "n" arrivals, and the average length of stay is estimated from a sample of "n′" patients (where $- n \gtrless n'$) then the variance estimate of the critical number is:

$$\hat{var}(C) = C^2(1/n + 1/n')$$

Thus the actual demand is based on the theory of a many server queue with random arrivals and negative exponential service time. The problem is what happens to the average waiting time if the rate of arrivals varies, but remains random in character? This situation occurs in the winter when the demand for beds is higher than in the summer. In general there is an annual fluctuation in the waiting list length. However procedures to calculate the effect of such fluctuations in advance are not yet known, due to the analytical complexity of allowing for a time dependent mean for inter-arrival times.

The main criticism of the basic queuing theory model was set forth by M. S. Feldstein? He feels the model is innappropriate because demand is not an independent variable but rather a function of the supply and the length of the queue. When there is a scarcity of beds and long waiting lists, more work is done on an out-patient basis, while if the number of beds is increased, the hospitalization rate as well as the length of stay increases. Thus use of the "critical number" method generally shows that the supply of hospital beds for the current period in an area is the correct number for the current period. However this criticism hinges upon whether or not supply is a function of demand, or demand a function of supply or both supply and demand are endogenous. This problem of interrelatedness of supply and demand will be investigated in the next chapter.

## 2.5 Multiregional patient flow model

This analysis for estimating the need for hospital facilities was developed by the Hospital Planning Council for Metropolitan Chicago.[8] The main features of this method according to its authors is that it can measure with precision the amount of hospital care used by a population of each geographical segment of a metropolitan area, as well as determine where the patients of each community go for their hospital care.

This method includes certain factors which are deemed to determine what the bed-population ratio should be. These factors are:

1-) population - measured as the number of people in a certain area at a specified time. Classified by age, sex and various socio-economic characteristics.

2-) rate of admissions - measured as the annual number of admissions in a certain area at a specified time per 1000 of the area's population.

3-) average length of stay - measured as the total number of patient days per year in the specified area, divided by the number of admissions from that area's population.

4-) average occupancy level - measured as the total number of patient days of service rendered per year by all hospitals in the specified area, divided by the total number of bed-days available per year in those hospitals.

The simplest formula that incorporates all of these factors and measures the actual bed use for a defined population is the following:

1-) $B = (P/1000) * (R * S)/(365 * L)$

where $B$ = beds

$P$ = population

$R$ = admission rate

$S$ = average length of stay

$L$ = average occupance level

This formula however is too simple to be used for any type of planning. The insection of actual data on population, admission rates, average length of stay and occupancy level would only measure actual bed use for the entire area and not an estimate of bed need.

For planning purposes this basic formula can be adopted to estimate the future bed requirements of a region, as will be seen below.

2-) Measurement of gross bed use (for base year)

$$GBU_b = (P_b/1000) * (R_b * S_b)/(365 * L_b)$$

where $b$ = subscript for the base year

$GBU_b$ = gross bed use

$P_b$ = region's population in the base year

$S_b$ = actual average length of stay of the region's patients in the base year.

$L_b$ = actual average occupancy rate of the existing hospitals in the region in the base year.

$R_b$ = admission rate in the region for the base year.

3-) Measurement of gross bed need (for prediction year)

$$GBN_n = (P_n/1000) * (R_n * S_n)/(365 * L_n)$$

where $n$ = subscript for prediction year.

$GBN_n$ = gross bed need in prediction year.

$P_n$ = region's projected population for the prediction year.

$R_n$ = desired admission rate for the region's population for the prediction year.

$S_n$ = desired average length of stay of the region's population for the prediction year.

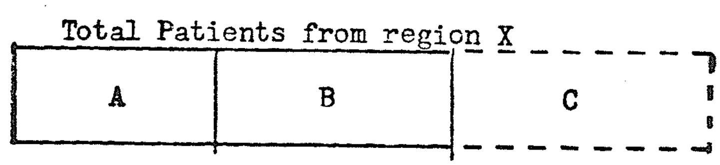
$L_n$ = desired average occupancy level for the region's hospitals for the prediction year.

The estimation of the bed use formula gives one an idea of the existing regional pattern of hospital demand. It also serves as a check that all factors used are consistent with one another; and can serve as a basis for determining desirable future admission rates, lengths of stay and occupancy levels for the region, to be used in equation 3-).

Once an area to be studied has been divided into suitable catchment regions, steps must be taken to determine the specific bed needs of each region. Measurement of the flows of patients among regions (eg. Metro Winnipeg and the rest of Manitoba as two regions of one area, Manitoba.) must be undertaken to ensure dependable estimates of future bed needs in each region.

A diagram of these interregional patient flows would be helpful.

4-)



where A = Patients from region X obtaining care <u>outside</u> of region X.

B = Patients from region X obtaining care <u>within</u> region X.

C = Patients from outside of region X obtaining care <u>within</u> region X.

Thus A measures the outflow of region X's patients to other regions, while B measures the patients of region X remaining in region X for hospital care. C measures the inflow of patients from outside of region X obtaining hospital care within region X. Thus the bed needs of a particular region depend upon B+C and not A+B. If region X has no hospital facilities then the bed needs of the region depend upon A.

Now, if flows of patients from one region to another are to be taken into account, the basic bed need formula has to be adjusted to measure bed needs for a region's local B-type patients only. A new formula then has to be devised to take into account the inflow of C-type patients.

5-) Regional bed needs for care of local (B-type) patients

$$BN_n^B = (P_n/1000) * (R_n * E_n * S_n)/(365 * L_n)$$

where B = superscript for B-type patients.

n = subscript for prediction year.

$BN_n$ = region's B-type bed needs for the prediction year.

$P_n$ = region's projected population for prediction year.

$R_n$ = desired regional admission rate for prediction year.

$E_n$ $\equiv$ estimated percentage of local (B-type admissions for prediction years.

$L_n$ = desired average occupancy level for region's hospitals for the prediction year.

$S_n$ = projected average length of stay for B-type patients.

This bed need formula has been revised to incorporate two projection variables:

a-) a projected percentage of local admissions is introduced explicitly into the formula.

$$\%\ \text{local (B-type) admissions} = \frac{\text{region's B-type patients}}{\text{region's (A+B) type patients}}$$

b-) the average length of stay is adjusted to apply only to local B-type patients.

A valid formula to estimate bed needs for C-type outside region patients is now needed. This problem is complex for multiregional areas, because of the flows of patients from one region to every other region.

Instead of accounting for the cross flows individually, an aggregative technique can be used. Over the whole area in consideration, the flows between the regions within the area must balance out. Thus the sum of A-type patients added up for all regions within the area must equal the sum of the C-type patients for all the regions.

A greater degree of precision than this is needed because some patients may be coming from outside the defined area (eg. outside of Manitoba). The A-type patients, as previously defined, are those who leave regions within the defined area and enter hospitals in other regions which are also within this area. C-type patients, however, include patients coming into regions from regions outside the defined area. Thus for precision, all patients from outside the defines area (eg. outside Manitoba) should be regarded as A-type patients from one additional region and should be included in the total of A-type patients over all regions ($\sum A+$). The balance equation then becomes $\sum C = \sum A+$ .

This balancing makes it much easier to determine C-type bed needs. Using the following formula to calculate A+type patient days:

6-) Patient days for A+type patients

$$PD_n^A = (P_n/1000) * (R_n * E_n * S_n^A)$$

where A = superscript for A-type patients.

n = subscript for prediction year.

$PD_n^A$ = region's projected A-type patient, days for the predicted year.

$R_n$ = desired regional admission rate for the prediction year.

$E_n$ = estimated percentage of A-type patients going out of the province for the prediction year.

$S_n^A$ = projected average length of stay of A-type patients going outside the region for the prediction year.

$$PD_n^{A+} = \sum PD_n^A + (a_n * L_n)$$

where $PD_n^{A+}$ = projected area A+type patient days for the prediction year.

$\sum PD_n^A$ = regional projected A-type patient days for all (i.e. $\sum$) regions in the prediction year.

$a_n$ = projected number of patients per year from outside the area for the prediction year.

$L_n$ = projected average length of stay for these patients coming from outside the area.

Using the balance equations $\leq C = A +$ the resulting total represents the total number of projected C-type patient days for which beds will have to be provided over the defined area. Every region within the area will be allocated C-type patient days depending upon each region's drawing power for outside patients as calculated by the formula.

7-) ADP = PD/TPD

where

ADP = region's actual drawing power

PD = patient days rendered annually by this region's hospitals to patients from outside the region.

TPD = total patient days rendered annually by all defined area hospitals to patients outside their own region.

thus ADP = $\frac{\text{region's C-type patient days}}{\leq \text{C-type patients in all the regions within the area}}$

PDP = % of defined area C-type patient days expected to be rendered by this region in the prediction year.

where PDP = region's projected drawing power.

Then the result of 7-) the region's drawing power, multiplied by the result of 6-) the projected total of patient days gives each region's share of outside patient days. One final step is then needed to estimate the C-type beds needed in a region.

8-) Regional bed needs for care of (C-type) outside patients

$$BN_n^c = (\leq PD_n^{A+} * PDP) / (365 * L_n)$$

where

$c$ = C-type patients

$n$ = prediction year

$PD_n^{A+}$ = $\leq A^+$ type patient days projected for the defined area for the prediction year.

PDP = region's projected drawing power.

$L_n$ = desired average occupancy level for the region's hospitals for the prediction year.

The total regional bed need can then be determined by adding the regional B-type and C-type bed needs together. Comparing these figures with the already existing supply of beds one can find if a region should increase or eliminate bed facilities.

In making use of this method, all regions should be dealt with simultaneously rather than in a partial analysis of each region. Hospital construction in one region would increase B-type patients and decrease that region's outflow of A-type patients. This would in turn reduce C-type beds in other regions. Thus increasing the number of beds in one region may reduce the need in other regions thereby making patient flows an important planning factor.

There are, however, significant advantages in the application of this type of formulation over a simple bed-population or bed-death ratio.

a-) Factors are identified which can be related to community characteristics in ways not possible by the more simplistic uniform bed-population and bed-death ratio. Regional distributions of age, sex, and income can be related to admission rates and length of stay, while the pattern of medical practice can be related to the length of stay, while the sizes and types of hospitals can be related to occupancy levels.

b-)The equations can be adopted to obtain a precise determination of regional needs for all the diagnostic categories, as well as to the needs for different levels of service comprehensiveness.

However, this method of analysis also has certain shortcomings. Determining desirable future admissions, length of stay and occupancy levels, are inevitably matters of policy and value judgements. What is needed is a complete planning model for the health care sector. If the number of admissions is reduced more work may have to be done on an out-patient basis, therefore recuiring alternate facilities. If the average length of stay is decreased, this may also entail further expenses on an out-patient basis. Thus manipulation of these variables indirectly influences other areas of the health sector so that decisions to alter these variables must be looked upon in the light of the whole spectrum of health care facilities.

## 2.6 Demand model analysis

This model makes use of a widely applied tool of statistical analysis, namely the use of least-squares multiple linear regression. The model estimates utilization of hospitals for a certain area by making use of a combination of sociodemographic and economic characteristics. What is wanted is an estimate of demand which specifically considers prices, incomes, tastes and preferences of the population to be served.

The choice of the variables in the framework will determine the models predictive ability, plausibility and simplicity. The criterion of simplicity tends to contradict the criterion of prediction, in that simple models often suffer from low predictive potentialities. The model in its mathematical form is as follows:

$$Y^i = a + b_1 x_1^i + \ldots\ldots\ldots + b_n x_n^i + e_n$$

where $Y^i$ = index of utilization in an area i

$x^i$ = characteristic variables of area i

a and bj = parameters of the demand relationship

e = error variable

The model then relates to what extent and what manner each of the x's, or independent variables relates to the utilization index or dependent variable. The error term reflects to what degree non-systematic, or random errors affect the utilization rate. The purpose of this technique is to yield insights into the relative impact of the particular variables which affect regional use of hospital facilities.

The choice of variables in any econometric model may result in imperfect specification of the model due to some linearly dependent variables which are not specifically included in the model. The variables selected in this study were felt to be of important predictive value. The literature on hospital bed requirements substantiated the selection of these variables. In general, the variables selected displayed the morbidity characteristics of those factors considered to have an important effect on hospital utilization.

This indices of utilization ($Y^i$) which could be used are a-) patients days per 1000 population b-) the admission rate per 1000 population and c-) the average length of stay. The (so-called) "independent" variables can be divided into sociodemographic and economic variables.

1-) Age - The association between age and hospital utilization is positive, as one could logically expect. Numerous studies [9,10] have unanimously concluded that as individuals age, the incidence of morbidity increases.

2-) Marital status - Similarly, other studies have concluded that there is a negative relationship between utilization and marriage. This was explained through the impact of marital status on the average length of stay and on patient days. Households may act as a substitute so that married persons can obtain more care without hospitalization. This conclusion was substantiated by a study of the Saskatchewan Hospital Services.[11]

3-) Sex distribution - It has been found in certain studies [12] that a population with a higher proportion of males would result in greater utilization because males had a higher average length of stay than females. While it could be shown that females in child bearing ages showed higher utilization no explanation could be given of the male phenomenom.

4-) Degree of urbanization - In the Saskatchewan study it was found that there was a relationship between density of population and hospital utilization. The rural areas with fewer persons per square mile seem to yield higher utilization rates.

5-) Distribution by race - This variable which is important in studies[13] in the United States, indicated a higher incidence of disease among non-whites as well as a higher mortality rate.

6-) Educational level - Work done in this area[14] showed that there was a high association between educational level, income level and expenditures for health.

7-) Population per dwelling unit - One study found that the association between the variable and the utilization of hospital facilities negative. The greater the population per dwelling unit, the lesser the utilization of hospital facilities. This may be a result of home facilities being an alternative to hospitalization as well as showing family responsibilities. However it is more likely due to socio-economic reasons - tenement dwellers are high density, low income people etc.

The economic variables which could be investigated are as follows:

1-) Price variations - In studies[15] in the United States this variable is quite important because there is no comprehensive medicare scheme. Thus price shows a negative relationship with respect to utilization. It was found that as insurance coverage of the population increased utilization rates increased thus implying that prices were deterrent for elective services in hospitals.

2-) Income distribution - The relationships between income and utilization rates was found to be positive in Rosenthal's study.

However the correlation was not significant in this study implying that income was not a crucial factor.

3-) Proposition with insurance - Numerous studies[16,17] have shown that areas with greater proportion of the population insured did have greater utilization rates. Thus insurance and utilization are positively correlated.

These variables were deemed the most important in the literature as to their effects on hospital utilization. However, in Manitoba certain economic variables such as price and insurance are of little use due to a comprehensive medicare scheme which is not in use in the United States.

Furthermore use of a model with a large number of independent variables requires a large number of observations. Thus the use of repeated observations in time is precluded due to the lack of data over a long period of time. Cross-sectional data is also a source of problems due to the fact that cross-sectional data should investigate hospitals of relatively the same size. With the large number of different hospital sizes in Manitoba we again run into a problem of insufficient data. If all hospitals in Manitoba were of relatively the same size a cross-sectional study would be useful, but unfortunately this is not the situation. Furthermore one would probably find, a highly complex correlation structure among the "independent" variables which would result in their being of little informative value. Thus with the large number of "independent" variables in such a model and the lack of sufficient data in Manitoba use of multiple regression demand models would not be too fruitful.

2.7 Pressure index demand model

The following demand model was developed by G. D. Rosenthal[15] for the American Hospital Association. The model estimates utilization of hospitals for a certain area by using certain economic and sociodemographic variables which were discussed above. The novelty of his approach does not lie in the use of multiple linear regression techniques but in the development of a pressure index from which he predicts future levels of hospital demand.

The first step in his technique was to use the previously defined demand model and make estimates of utilization or demand. Having done this, estimates of needed patient-days capacity that would represent a uniform pressure on all areas were made.

An estimate of a maximum occupancy rate was arrived at by a method using the given size of a hospital and a given probability of its being fully utilized. The question asked was "Given a hospital of a certain size, what is the average daily census which will cause it to be filled to capacity no more than a given proportion of the time?"

In order to answer this question a model was developed based upon the characteristics of the Poisson distribution. It was assumed that the admission of a patient into a hospital was a rare event relative to the size of the population in which it occured. Furthermore it can be shown that the sum of a number of Poisson distributions is also

Poisson distributed. The daily census of any hospital is made up of random admissions, thus seemingly justifying the assumption of a Poisson distributed daily census. Having established the average daily census one can speculate upon the characteristics of the complete distribution, assuming of course that the census is Poisson distributed. This is made possible because given the average daily census (the mean), it is possible to determine the size of facility necessary to accommodate any given percentage of the distribution. Also, given a fixed probability level of the facility being full, and given the size of the hospital, one can calculate the average daily census.

The procedure then required two further assumptions:

a-) the maximum occupancy rate for each area will be based on the average size hospital of the area.

b-) the maximum occupancy rate will be that level of occupancy at which facilities will be full not more than a given number of days in 100.

For example, given the Poisson distribution:

$$f(x) = \frac{e^{-m} m^{x}}{x!}$$

where m - average daily census
x - any given census

$$\sum_{x=0}^{\infty} f(x) = 1.00$$

then $$\sum_{x=0} f(x) = .99 \quad \text{or} \quad .99 = \sum_{x=0}^{X} \frac{e^{-m} m^{x}}{x!}$$

is the probability that the hospital will be full not more than 1 day in 100.

Knowing the average size of the hospitals in every area under investigation, the average daily census for the average size hospital can be found. Having done this the maximum occupancy rate for every area can be calculated:

$$\text{Maximum occupancy rate} = \frac{\text{(estimated) daily census}}{\text{average size hospitals}}$$

Once having obtained the maximum occupancy rate; use can be made of the utilization estimates in patient days per thousand to obtain an estimate of the patient-days capacity needed to meet the peak demand. These capacity estimates can then be translated into estimates of beds needed in each area by dividing by the number of days in the year (365). The result will be the number of beds needed per 1000 population in each area, taking into consideration each areas different sociodemographic and economic characteristics.

Example:

Suppose the average size of the hospitals in an area to be investigated is 92.5 beds. Making use of the demand relations in the demand model the estimated demand for patient-days per thousand in the area is 1,002.1. Assuming also that an acceptable probability is that the occupancy rate of the hospital will be full not more than one day in 100. One can then use the Poisson distribution to estimate the average daily census of the hospital.

$$f(x) = \frac{e^{-m} m^{x}}{x!}$$

$m$ = average daily census (to be estimated)

$x$ = size of the hospital

$$\sum_{x-o}^{92.5} f(x) = .99$$

for x = 92.5

$$.99 = \sum_{x=o}^{x=72.5} \frac{e^{-m} \quad m^{x}}{x\,!}$$

Solving for "m" through the use of cumulative Poisson probability tables we get;

m = 73 (estimated daily census)

Substituting into:

$$\text{Maximum occupancy rate} - \frac{\text{(estimated) daily census}}{\text{size of the hospital}}$$

$$= \frac{73}{92.5} = 79\%$$

Translating this estimate into capacity needed in terms of patient days per thousand:

1,002.1 ÷ .79 = 1,270

This can then be translated into the number of beds needed per 1,000 population.

1,270 ÷ 365 = 3.5 beds per 1000 population

Comparing this figure in the hypothetical example to the existing number of beds per 1000 population in the example, one can see whether an area has too many or too few beds.

This model differs from the previous models in that it takes into consideration the fact that utilization rates between hospitals do not necessarily indicate the relative use made of the facilities. Two hospitals may be of the same size and have the same utilization rates but may show different degrees of pressure. Since an optimal spatial distribution of hospitals is desirable on economic grounds, making use of a pressure index can indicate which areas need larger or smaller hospital facilities or where we need better transportation. Doing so will result in a uniform utilization of facilities in all regions. Thus such a model could ensure that all people in an area (such as Manitoba) would have the same availability of hospitals at their disposition at all times given their morbidity characteristics.

An important criticism of Rosenthal's model has been stated by Feldstein.[7] Feldstein feels that all manifest demand approaches ignore the effect of available bed supply on the demand for hospital admissions and on the average length of stay per case. If supply, that is the number of beds available is increased, the parameters of the demand equation would change, indicating higher levels of predicted demand. He also questions Rosenthal's use of social and economic variables in the regression equations which influence the demand for hospital care. Omitting the available number of beds from the bed demand equations is according to Feldstein a serious misspecification that will assuredly have sizeable effects on each of the other coefficients.

2.8 The applicability of these methods to Manitoba

The first two methods, the bed-population ratio and the bed-death ratio can be discarded by looking at the results of their usage in the United States. Both methods seem to overestimate the demand for beds and therefore can result in serious overbuilding of hospital facilities. Furthermore the theoretical difficulties in justifying their use are overwhelming. The choice of any particular ratio is made without a strongly defensible basis of selection. Thus it seems that these two methods involve too many difficulties to be of any value for the situation in Manitoba.

The third method examined, the queueing theory model, depends upon quite stringent assumptions. The assumption that patients recover at random is a debatable question. It could be that each particular diagnostic category has a norm set by prevailing practice which cannot be easily broken. In such a case patients do not recover at random. Had the model proven to be of use, data problems however would have precluded its use. Waiting lists for hospitals in Manitoba are not available.

The multiregional patient flow model warranted further consideration. The flow of patients between regions of an area under study is important in determining in which regions hospital facilities are deficient. Such a model could not only look at the flow of patients, but adapted to a linear programming framework it could minimize patient as well as physician travelling time. In spite of its merits, such a model requires such horrendous amounts of data which were not easily accessible that it could not be used. However a major study using this technique would be fruitful. Of all the models investigated the multi-regional patient flow model was the most realistic and seems to be the most appropriate model in determining future hospital bed requirements. As previously mentioned the only reason this method was not used was due to the data problems and the time and cost involved in its application.

The multiple linear regression model seems to be the most appropriate supply prediction model. It has the theoretical advantage of being able to incorporate into its prediction, changes in the underlying factors believed to influence hospital use. The ability of this model to incorporate relevant variable seems to be its major asset.

However, these variables lack importance to Manitoba. Due to the medicare scheme persons living in Manitoba have free accessibility to all hospital facilities. The price variable has no effect on utilization because compulsory annual premiums ensure the payment of hospital bills.

However, there are opportunity costs such as foregone income which a person incurs while in the hospital. These may still affect persons in lower income levels, to the extent that they have no fringe benefits such as sick pay when in the hospital. Income however may affect utilization through education. Persons with higher levels of education are those that tend to utilize hospitals to a greater degree. Furthermore in previous studies it was found that persons with high levels of income also had a greater than average health insurance coverage. The correlation between insurance coverage and utilization were also quite high. In Manitoba however, the income variable is probably negligible due to the medicare scheme. Thus the economic variables in this method are of little use in Manitoba.

The sociodemographic variables however, can provide us with some insights. Such variables as marital status, degree of urbanization, race and educational level may be of some benefit but the cost of gathering such data as well as the time constraint discounted their value. The population per dwelling unit was not only excluded because of lack of data, but because the medicare scheme would make negligible such a variable's influence. The six distribution as well as the age distribution however, were measurable because of the availability of data.

These multilinear regression models do not only contain irrelevant variables for Manitoba but also require extensive date requirements. Even if part of the data requirements could be overcome the use of time series and cross-sectional methods would still require a large number of observations to be of any use. Finally, multilinear regression models take account of linear dependencies only. Non-linear relations between "y" and the "$x_i$" and a highly significant correlational structure among the "$x_i$" weakens the descriptive and predictive power of the model and it still wouldn't separate supply and demand.

Because of these points, the multilinear regression models were not used in Manitoba. Instead of using one specific model that had been used elsewhere, a model was constructed to take into consideration the special characteristics of Manitoba. This model will be elaborated upon in a subsequent chapter.

Footnotes:

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# CHAPTER THREE

# THE INFLUENCE OF SUPPLY

## 3.1 Introduction

One argument that is extensively used whenever a study of the demand for hospital facilities is undertaken is that the supply of hospital facilities creates its own demand. It is felt that demand analysis does not provide an acceptable estimate of the need for hospital beds. Whenever the supply of hospital beds increases, ceteris paribus, doctors tend both to hospitalize patients more readily and also to hospitalize patients for longer periods. This argument amounts to a Say's law for hospital facilities, that is supply creates its own demand.

In this chapter an attempt will be made to see whether or not this hypothesis applies to the situation in Manitoba. The issues to be examined are = does supply create its own demand, does demand influence supply or are both supply and demand so interrelated that one cannot distinguish their respective influences. In the first section we will examine the effects of availability (supply) on bed demand. In the second, we will investigate the role of demand and how it affects supply as well as adjudicate the relative merits of each argument.

## 3.2 Effects of bed availability on their demand

Variables which are deemed important as measures of hospital facility demand by other studies of this nature suggest that the age-sex composition of the population, the availability of general practitioners and out-patient services as well as the incidence of disease, price variations, income distribution, proportion of the population with insurance, education, are important characteristics that determine the level of demand. Interviews conducted with doctors in Manitoba and substantiated journal article findings[1,2] held that the availability of beds not only affects the number of admissions but the average length of stay. The contention among those interviewed was that whenever beds were scarce and waiting lists quite lengthy, more work was done on an out-patient basis and the average length of stay was relatively short. Thus one would expect that as the availability of beds increased in a region, such measures of hospital utilization as admissions or patient days would also increase, with the duration of stay tending to lengthen. What remains is to establish a correlation and to try ascertain which hypothesis is the most plausible in Manitoba.

The method used was to correlate various measures of hospital utilization with comparable figures on hospital bed availability. Four measures of hospital demand used were a-) the number of admissions (or separation) per 1000 population b-) the number of hospital beds used[3] per 1000 population c-) the patient days per 1000 population d-) the percentage occupancy level.

The measures of supply which were used are a-) the number of hospital beds per 1000 population b-) the average length of stay and c-) the percentage occupancy level. The total number of beds used could have been employed but instead the number of beds per 1000 population was selected. The use of "total beds used" as an index of supply raises problems. Even though the availability of beds can be treated as an exogenous variable, the total number of beds used could indicate demand as well as such exogenous factors as supply, accessability and hospital size. These considerations precluded the use of the "total beds used" as a supply measure.

In order to increase precision and to ease interpretation, the Manitoba hospital system disaggregated into two areas. The behavioural patterns of the Manitoba system as a whole were analyzed, followed by a breakdown into Metropolitan Winnipeg and the Rest of Manitoba. This disaggregation was used because it differentiated between hospitals which were strictly urban in character and hospitals that were predominantly rural. Furthermore, the urban hospitals, mainly those in Metropolitan Winnipeg accounted for 60% of the total number of hospital beds in the province of Manitoba. In addition, only active treatment hospitals were analyzed.

One of the main proponents of the thesis that supply creates demand is M. S. Feldstein. By correlating the aforementioned demand and supply indices as well as the correlation between percentage utilization and bed availability, coupled with the particular characteristics of England and Wales he concluded that supply creates its own demand, though such data can equally well be explained if demand creates supply.

He found a high correlation between beds used and beds available (.84) with a low correlation between percentage utilization and bed availability (-07). To substantiate his claim he stated 1) nearly half of the hospitals he had investigated were more than 70 years old, 2) there had been no construction for almost 25 years and 3) all patients treated in a region were also residents there. Supply did not adjust to demand by the temporary migration of patients.

Given this interpretation the high correlations would be a warning against the use of measured demand as a planning guide. "If the observed demand actually reflects available supply, it cannot serve as the basis for estimating what the supply should be."[6] To further substantiate his claim Feldstein attempted to describe the data by making use of various relationships.[7] He found that as availability (supply) increases bed-day demand did not tend to a limit, the data seemed to indicate that, at least within the observed range of supply, bed-day demand increases proportionately with availability (supply). The various models he used were:[8]

1-) a proportional linear relationship

$$D_3 = \underset{(0.861)}{0.205} + \underset{(0.158)}{0.726}\ S \qquad R^2 = 0.702$$

2-) proportion of beds used

$$\frac{D_3}{S} = 0.800 - \underset{(2.952)}{0.649}\ S \qquad R^2 = 0.005$$

3-) a quadratic as in (1-)

$$D_3 = 1.653 \quad \underset{(2.900)}{0.209S} + \underset{(0.026}{0.005S^2} \qquad R^2 = 0.706$$

4-) a quadratic as in 2-)

$$\frac{D_3}{S} = 0.81 - \underset{(0.54)}{0.01S} + \underset{(0.0479)}{0.0004S^2} \qquad R^2 = 0.005$$

5-) a logarithmic - reciprocal transformation

$$\log D_3 = 2.406 - \underset{(1.204)}{5.319}\ S^{-1} \qquad R^2 - 0.684$$

or

$$D_3 = e^{2.406 - 5.319\ S^{-1}}$$

where $D_3$ = number of beds used per 1000 population

$S$ = number of beds available per 1000 population

The quadratic equations in 3-) and 4-) had second order terms which were insignificant and of "incorrect sign". Also the inclusion of a second order term did not increase the equations" explanatory power as indicated by the multiple correlation coefficients. Equation 5-) in exponential form suggests that demand has an upper limit of 11.1 beds used per 1000 population ($e^{2.406} = 11.1$). However this figure is of little value because the range of observations is insufficient to indicate that an S-shaped curve should be chosen in preference to a straight line. The point of inflection ( $S = 2.66$) is far below the level of the lowest observed supply in his data. Thus there is no reason to accept this equation in preference to the simpler straight line.

Feldstein then concluded that the demand for bed days increases proportionately with supply. Present experience did not seem to indicate that there was a level of supply capable of satiating bed-day demand.

Similar correlations were calculated for the Metropolitan Winnipeg area, the Rest of Manitoba as well as all of Manitoba and are contained in tables 3.1 and 3.2.

For all of Manitoba the correlation between beds used and beds available is (R = .683). The correlation between the number of admissions and the beds available is (R = .711). The correlation between percentage occupancy and beds available is (R = - .252). The variation in observed demand can be explained by availability differences: 50.6% if demand is measured as the number of cases treated (separations), 46.6% if beds used in the adopted measure. Beds used is less highly correlated than cases treated because the average length of stay tends to decrease when more beds are available.

These correlations were calculated from data which included all of the hospitals in the province of Manitoba. The correlation coefficient is an index designed to give an immediate picture of how closely two variables move together.

The Manitoba correlations are not too meaningful until they are disaggregated into Winnipeg and the Rest of Manitoba. In Greater Winnipeg the correlation between beds used and beds available is (R = .607). The correlation between admissions and beds available is (R = .493), while the correlation between percentage occupancy and beds available is (R = .410).

In Winnipeg it seems that observed demand may not necessarily be influenced by the availability of beds. Only 24% of the bed availability differences can indicate the level of observed demand, which is an interaction of demand and supply. If demand is measured as the number of beds used per 1000 population only.

Table 3.1 Correlations of bed demand and availability for Manitoba

| Demand Measure | Supply Measure | Hospital beds per 1000 population | Average length of stay | % occupancy |
|---|---|---|---|---|
| Admission per 1000 population | | R = .711 | R = .037 | R = .313 |
| | | $R^2$= .506 | $R^2$= .001 | $R^2$= .098 |
| Patient days per 1000 population | | R = .753 | R = .671 | R = .414 |
| | | $R^2$= .568 | $R^2$= .450 | $R^2$= .172 |
| % occupancy | | R =-.252 | R = .293 | * |
| | | $R^2$= .064 | $R^2$= .086 | |
| Beds used | | R = .683 | | |
| | | $R^2$= .466 | | |

Table 3.2 Correlations of bed demand and availability for Winnipeg

| Demand Measure | Supply Measure | Hospital beds per 1000 population | Average length of stay | % occupancy |
|---|---|---|---|---|
| Admission per 1000 population | | R = .493 | R =-.312 | R = .484 |
| | | $R^2$= .243 | $R^2$= .097 | $R^2$= .234 |
| Patient days per 1000 population | | R = .489 | R = .154 | R = .540 |
| | | $R^2$= .239 | $R^2$= .024 | $R^2$= .292 |
| % occupancy | | R =-.410 | R = .245 | * |
| | | $R^2$= .168 | $R^2$= .060 | |
| Beds used | | R = .607 | | |
| | | $R^2$= .368 | | |

Table 3.3 Correlation of bed demand and availability for the rest of Manitoba

| Demand Measure | Supply Measure | Beds per 1000 population | Average length of stay | % occupancy |
|---|---|---|---|---|
| Admission per 1000 population | | R = .975 | R = .460 | R = .431 |
| | | $R^2$ = .951 | $R^2$ = .212 | $R^2$ = .186 |
| Patient days per 1000 population | | R = .993 | R = .667 | R = .413 |
| | | $R^2$ = .987 | $R^2$ = .445 | $R^2$ = .171 |
| % occupancy | | R = .348 | R = .127 | * |
| | | $R^2$ = .121 | $R^2$ = .016 | |
| Beds used | | R = .993 | | |
| | | $R^2$ = .985 | | |

36.8% of the difference in availability can, in this case, explain observed demand. Thus in the Winnipeg area, it seems that the level of demand cannot readily be explained by the supply of beds available.

The correlations for the rest of Manitoba however, were quite startling. The correlation between admissions and beds available is R = .975. The correlation between beds used and beds available is even higher at R = .993. The correlation between beds available and the occupancy rate is R = .348. This is a low but positive correlation. This could indicate that as the supply of beds was increased over the years, the average size of hospitals had decreased, therefore increasing the occupancy rates. (Generally large hospitals have higher occupancy levels). If separations are used to measure observed 95.1% of observed demand can be explained by the availability of beds. If the number of beds used in the adopted measure 98.5% of the demand can be explained by the supply level of beds. The beds used index is more highly correlated than cases treated because the average length of stay also increases when more beds are made available.

These substantial correlations could either mean that supply had been adjusted in past years to satisfy an exogenously determined demand, regional levels of demand have adjusted themselves to an exogenous level of supply or demand and supply are both endogenous and interacted with each other and other factors, especially some function of time such as population growth over time, in a way that produced the observed correlations. If supply had adjusted to demand the size of the correlations would indicate the success with which supply had adjusted to demand pressures.

For the Winnipeg area the low correlations seem to be an indication that supply does not create its own demand. In the Rest of Manitoba, the correlations are extremely high. However we cannot appeal to "a previous distribution of population and a past type of medical care" as Feldstein does. The number of available beds per 1000 population have been continuously changing in Winnipeg and the Rest of Manitoba since 1962. Various hospital facilities have been built in both urban and rural Manitoba in the time interval studied. Furthermore, there is a certain migration of rural patients to

Winnipeg whenever rural facilities are lacking in specific areas of hospital care facilities.

Thus an appeal to Feldstein's approach in order to determine whether Say's law (i.e. supply creates demand) applies to hospital facilities in Manitoba does not lead to conclusive results. In the next section an attempt will be made to determine whether demand determines supply or whether supply determines demand.

### 3.3 The role of demand

In the previous chapter it was argued that the average daily census of a hospital could reasonably be assumed to follow the Poisson - distribution. An important characteristic of this distribution is that it is completely determined by the mean. Thus if one knew the average daily census of a hospital, it would be possible to determine the size of the facility necessary to accomodate all patients any given percentage of the time. Or alternatively, given the maximum census of a hospital and a fixed probability that this given census will be exceeded, the average daily census of the hospital can be estimated. The fixed probability could be that level of occupancy at which the facilities will be full not more than one day in 100 or

$$\sum_{x=0} f(x) = .99.$$

Thus given knowledge about the average daily census and hospital size an index of maximum occupancy rate[10] can be calculated as follows:

$$\text{Maximum occupancy rate} = \frac{\text{average daily census (estimated)}}{\text{average size of the hospital}}$$

These estimates of maximum occupancy rates provide an identical probability of each hospital in the province being fully utilized. These estimates represent theoretical points of uniform pressure on hospital facilities. Using these estimates an index can be constructed which measures the relative pressure on each hospital facility within a region.

$$\text{Pressure index} = \frac{\text{observed occupancy rate}}{\text{maximum occupancy rate}} \times 100$$

Making use of this pressure index for hospitals in the Winnipeg area and in the Rest of Manitoba one can get an idea of the relative demand pressures on the facilities in both an urban and rural setting. These calculations were made for all active treatment hospitals in the province of Manitoba for the years 1962 and 1968 permitting a comparison of the effect of supply changes on the pressure of facilities or of the effect of pressure on construction of facilities. The probability level used was that the facilities would be full not more than one day in 100 (i.e. probability = .99. The rationale for this probability level is that the model breaks down at higher probabilities of a hospital being full (>5%). This is because when a hospital fills up and waiting lists form, the observations on consecutive days are not independent Poisson variates (i.e. if a hospital is full on day $\theta$, it is likely to be full on day $\theta+1$ as well). Furthermore the model seriously overestimates the permissable mean occupancy allowable for the probability of a hospital being full $\geq$ 5% of the time.

If the supply of beds were greater in one period as compared to a previous period, there would be two possibilities. If the view that supply generated demand were correct, there would be no change in the pressure on facilities because the "excess" facilities would be used to the same degree (i.e. demand would adjust to an exogenous level of supply). But if demand reflects the characteristics of the population rather than the exogenous levels of supply, then the result of a greater supply on the area should be a lower degree of pressure on facilities.

Through an examination of the period 1962-68 it was found that most hospitals had experienced changes in their rated bed capacities. Decreases as well as increases in the supply of beds have taken place. In table 3.4 hospitals in rural Manitoba which experienced bed supply changes in this time period were recorded. In all but six of the hospitals that witnessed supply changes there was a negative relationship between the rated bed capacity and the pressure index. Thus as the supply of beds was increased the pressure index decreased, and conversely as the supply of beds diminished the pressure index showed an increase. Thus in the Rest of Manitoba changes in the supply of beds resulted in changes in the pressure index, thus giving an indication about the response (elasticities) of supply to demand.

Table 3.4 Pressure index - Rest of Manitoba

| | 1962 | | 1968 | |
|---|---|---|---|---|
| | Rated beds | Pressure index | Rated beds | Pressure index |
| Cartright | 8 | 89 | 7 | 113 |
| Elkhorn | 9 | 99 | 8 | 138 |
| Manitou | 10 | 190 | 14 | 81 |
| Arborg | 15 | 170 | 19 | 134 |
| Beausejour | 22 | 123 | 21 | 125 |
| Carberry | 16 | 184 | 29 | 111 |
| Deloraine * | 20 | 102 | 21 | 108 |
| Emerson | 8 | 285 | 18 | 113 |
| Eriksdale | 9 | 161 | 17 | 118 |
| Gilbert Plain | 10 | 219 | 21 | 109 |
| Gladstone * | 22 | 109 | 25 | 118 |
| Grandview | 20 | 137 | 17 | 153 |
| Killarny | 31 | 77 | 29 | 125 |
| McCreary | 8 | 221 | 16 | 119 |
| Melita | 22 | 73 | 17 | 107 |
| Preston | 15 | 124 | 17 | 86 |
| Rossborn | 16 | 105 | 17 | 88 |
| Ste-Anne * | 13 | 118 | 18 | 144 |
| St. Pierre | 21 | 116 | 19 | 138 |
| Swan Lake | 11 | 212 | 18 | 191 |
| Teulon | 20 | 134 | 23 | 116 |
| Treherne | 24 | 105 | 22 | 108 |
| Winnipegosis | 17 | 120 | 22 | 113 |
| Altona | 30 | 122 | 38 | 96 |
| Minnedosa | 25 | 135 | 35 | 108 |
| Neepawa | 35 | 94 | 34 | 120 |
| Pine Falls * | 28 | 70 | 48 | 122 |
| Souris | 34 | 110 | 33 | 121 |
| Winkler | 26 | 204 | 57 | 113 |
| Portage | 83 | 107 | 94 | 87 |
| Ste Rose * | 71 | 97 | 68 | 95 |
| Selkirk * | 74 | 107 | 77 | 107 |
| Steinbach | 39 | 136 | 65 | 99 |
| Swan River | 42 | 163 | 68 | 110 |

Table 3.5 Pressure index - Metropolitan Winnipeg

| | 1962 | | 1968 | |
|---|---|---|---|---|
| | Rated beds | Pressure index | Rated beds | Pressure index |
| Concordia | 79 | 101 | 73 | 108 |
| St. Boniface | 726 | 89 | 658 | 95 |
| Grace | 208 | 120 | 258 | 103 |
| Victoria | 145 | 107 | 135 | 109 |
| General | 918 | 91 | 967 | 92 |

Upon examination of the pressure indices in the Winnipeg area the same general pattern occured as in the Rest of Manitoba. The only exception was the Winnipeg General hospital, where an increase in the supply of beds from 918 to 967 coincides with no significant change in the pressure index. However taking into consideration the low correlation previously found between demand and supply, there seems to be little ground for believing that "supply creates demand" in the Winnipeg area. The evidence seems to show that supply may influence demand to a small degree, but it certainly cannot be interpreted as meaning that exogenous changes in supply automatically generate a demand for that supply.

Thus taking all factors into consideration the thesis put forth by Feldstein was not substantiated for either rural or urban Manitoba.

Footnotes:

1. Feldstein, M. S. "Effects of Differences in Hospital Bed Scarcity on Type of Use," British Medical Journal, Vol. 27, (August, 1964), pp. 561-64.

2. Roth, F. B. et, al. "Some Factors Influencing Hospital Utilization in Saskatchewan," Canadian Journal of Public Health, Vol. 46, (August, 1965), pp. 303-23.

3. Beds used = Beds available per 1000 population X percentage occupancy level.

4. Feldstein, M. S. "Hospital Bed Scarcity: An Analysis of the Effects on Inter-Regional Differences," (1965), Economica, p. 393.

5. Feldstein, M. S. "Hospital Planning and the Demand for Care," Bulletin of the Oxford Institute of Economics and Statistics, (1964) p. 361.

6. op. cit., p. 363 - his italics.

7. Feldstein, M. S. Economic Analysis for Health Services Efficiency, Markham Publishing Company, Chicago, 1968, p. 198,

8. The figures in parentheses beneath the coefficients in each equation are the standard error of the coefficient. As well no 6 - values were included in the literature.

9. Johnston, J. Econometric Methods, 1963, McGraw-Hill Book Company, New York, p. 31.

10. Rosenthal, G. D. The Demand for General Hospital Facilities, Hospital Monograph Series No. 14, American Hospital Association, Chicago, 1964, p. 50-57.

# CHAPTER FOUR

# DEVELOPMENT OF THE ANALYTICAL MODEL

## 4.1 Introduction

In the previous chapter an examination of alternative planning models was undertaken. The relative merits of each model were discussed as well as their applicability to Manitoba. The purpose of this chapter is to present a hospital facility utilization planning model which will not be subject to some of the difficulties inherent in the previous methods of analysis.

In the first section various factors that influence the demand for hospital facilities will be investigated. The model will entail a prudent selection of determinate variables, in the process discarding those variables whose influence is weak or indeterminable. In the second section the analytical model will be developed within the framework set out in section one. In the third section an examination of the estimation procedures used in the analysis will be undertaken, while in the last section the merits and demerits of the model will be discussed.

## 4.2 Factors influencing the demand for hospital facilities.

It is essential that the variables included in any statistical model be chosen on non-statistical grounds. In choosing the variables considered important there is always the danger of imperfect specification; namely that certain variables that are related to the dependent variable are not specifically included in the model. In view of the limitation of the data available this facet is quite important. The inclusion of many explanatory variables requires a large number of observations. Thus taking into consideration the data problems an attempt at isolating the most important variables will be undertaken by using the following considerations:

1. the advice of hospital administrators and medical doctors.
2. the frequency of their inclusion in the literature similar to the study.
3. a logical expectation of association between each of the explanatory variables and the utilization of hospital facilities.

Having selected the variables, a predictive model was chosen and fitted.

A survey of the literature in the area of hospital utilization brings to light a number of factors which have been considered by various researches as important predictive determinants. These variables can be separated into two classes; those of an economic nature and those of a sociodemographic nature. The sociodemographic variables were; the age distribution, the sex distribution, marital status, distribution by race, and the educational level. Variables of an economic nature were the price differentials of medical treatment, the income distribution of the population as well as the population with insurance coverage.

Certain studies have concluded that there is a negative relationship between hospital utilization and marital status. This was explained through the impact of marital status on the average length of stay. Households may act as a substitute so that married persons can obtain more care without hospitalization. This conclusion was substantiated by a study of the Saskatchewan Hospital Services.[1] Furthermore studies in Great Britain have shown that in proportion to the whole population, single, widowed, and divorced people used almost twice as much medical care as the married.[2] A study by the U. S. Public Health Service[3] also indicated that although married people of both sexes account for more discharges in proportion to their numbers than other segments of the population they tended to have a shorter average length of stay. Married females easily accounted for their higher proportion of discharges because of maternity cases, but no ready explantion is available for married males. Taking into consideration all of these factors it can logically be expected that those areas with a higher proportion of married persons would tend to show lower utilization rates. However this particular factor was not used in the predictive system because its influence was not felt to be significant.

The relationship between race and hospital utilization is quite difficult to ascertain as studies in the United States[4] have shown morbidity statistics supported the view that the incidence of disease among non-whites in the United States is much higher than among whites. Whether or not this relationship is the same in Manitoba is only conjectural. No information was available relating ethnic origin and race to hospital utilization, thus presenting an intractable barrier to empirical enquiry.

Another element investigated was the educational level. In the United States, the Health Information Foundation[5] observed a high correlation between the educational level, income level and expenditures for medical treatment. It is not easily ascertainable which variable, income or education, affects expenditures to a greater degree because education and income are positively related. Higher levels of education generally result in higher income, this education may act on the income variable which in terms generates higher health insurance coverage. Also it was found that people with less than nine years education had longer lengths of stay which offset the lower admission rate of this group.[6] This pattern of hospital utilization by the less educated group occurs in spite of the fact that a higher level of education is associated with a greater awareness of preventive and curative health needs. The result then of considering these two factors is that the influence of education on the degree of hospital utilization may either be positive or negative because the greater awareness of health needs results in both the prevention of illness and its early treatment. Since these studies could not determine the behavioural trend of education on hospital utilization, this variable was avoided in the predictive model.

Scanning the remaining factors immediately reveals that many of these influences may be relevant to the system of medical care in the United States but are of little significance in Manitoba. One such element that comes to mind is the proportion of people with insurance. Under the direction of the Manitoba Health Services Commission, Manitoba's health care programme has affected both the levels of hospital utilization and social participation. Under previous insurance programmes, when comprehensive medical coverage was optional, it was conceivable that such considerations as income distribution, hospital cost differentials and to a lesser degree educational levels and ethnic considerations might have affected the patterns of hospital utilization. Since the insurance coverage was based upon the ability of the individual to meet his insurance premiums, those able to afford broader coverage patronized hospital facilities to a greater degree. However, the present framework under the Manitoba Health Services Commission does not discriminate against those unable to meet its premium demands. Thus income is no longer an important determinant of hospital utilization in Manitoba, due to the accessibility to hospitals offered by the medicare scheme. Income however is closely related to age, sex, and in some cases location, thus factors integrally related to income may be important.

In the United States however, where health insurance coverage is not uniform across the population, studies[5] have shown that income is the greatest single determinant of the level of hospital utilization. It was found that high health expenditure families (those spending over $300.00 per year on medical care) were also those with a high level of annual income. In addition these families were also characterized by a high level of education as well as a greater than average health insurance coverage. In the United States as mentioned above, income is the greatest determinant of hospital utilization as well as insurance coverage. In Manitoba however, insurance coverage is enjoyed by the whole population thus diminishing the influence of the income variable except of course for the opportunity costs involved in seeking medical care. This consideration as well as data problems resulted in the income variable being discarded as an important predictive variable.

Of the remaining variables, age distribution, sex and the degree of urbanization were all regarded as important in determining the levels of utilization. The association between age and hospital utilization is positive as one would logically expect. Numerous studies have unanimously concluded that, as individuals age, the likelihood of morbidity increases. However this relationship is not linear. In age groups of 2-30 years the relationship is almost linear, but after age 30 the association is doubly exponential (i.e. prob. hospitalization - $k e^{c e^{a}}$). Usage tends to decline at first with age and then to increase. At the low end of the age scale high medical expense is expected in the child-bearing years. At the high end of the age scale it is expected that among the aged, highest usage will manifest itself as they become more susceptible to accidents and chronic illnesses. Chronic diseases which are characteristic illnesses of older people require longer duration of stays and more hospitalization than the acute diseases which are more prevalent among younger age groups.

The expectation is that areas with greater proportions of the population being older would also utilize hospital facilities to a greater extent. If in Manitoba it could be determined which areas are characterized by greater than average levels of elderly people, one could then expect higher levels of utilization and vice versa for concentrations of younger people. Due to the importance of this variable in morbidity trends as well as the availability of the data in the "Standard Supplements of the Manitoba Health Services Commission" it became an integral determinant in the model used.

Several studies on the relationship between sex distribution and utilization have been done in the United States.[8] These studies found that the admission rate for women tended to be higher, especially during the child-bearing ages, but this was offset by the longer length of stay noted for males. The expectation then, is that over the whole population, if there is a higher proportion of males then this would result in a greater utilization of hospitals, even though it was found that the association between admissions per thousand population and proportion of males might show a negative relationship. This sex distribution factor was included in the predictive model by determining the incidence of morbidity by diagnostic category, by sex, and then relating this to patient days and separations which then gives the average length of stay.

An examination of statistical records relating to admissions, patient days, average length of stay, percentage occupancy rate and rated bed capacity it was soon apparent that hospital utilization patterns differed markedly between Metropolitan Winnipeg and rural Manitoba.

Admissions per thousand population were always higher in rural areas as compared to Metropolitan Winnipeg. Patient Days per thousand however were a lot lower in the rural areas. Thus the result of these two factors is that the average length of stay is markedly lower in rural Manitoba as compared to Winnipeg. This can be seen in tables 4.1, 4.2 and 4.3.

The higher admission rates in the rural area may reflect the relative shortage of physicians. There is pressure on the doctor's time and it may be that admission to the hospitals is influenced by his need.to serve a larger number of people. The time factor may be further aggravated by the greater distance he has to travel. Furthermore the difficulty of getting to a hospital encourages the use of the hospital for preventitive care in that some patients may be directed to the hospital prior to examination. This may result in higher admission rates and a smaller number of patient days which tends to decrease the average length of stay.

**Table 4.1** Patient days per 1000 population for Winnipeg and Rural Manitoba for 1962 - 68

| Year | Winnipeg | Rural Manitoba |
|---|---|---|
| 1962 | 1785 | 1168 |
| 63 | 1850 | 1180 |
| 64 | 1881 | 1227 |
| 65 | 1852 | 1256 |
| 66 | 1767 | 1362 |
| 67 | 1720 | 1376 |
| 68 | 1747 | 1420 |

**Table 4.2** Separations per 1000 population for Winnipeg and Rural Manitoba for 1962-68

| Year | Winnipeg | Rural Manitoba |
|---|---|---|
| 1962 | 171 | 155 |
| 63 | 174 | 160 |
| 64 | 176 | 156 |
| 65 | 168 | 161 |
| 66 | 162 | 178 |
| 67 | 160 | 177 |
| 68 | 162 | 183 |

**Table 4.3** Average length of stay per 1000 population for Winnipeg and Rural Manitoba for 1962-68

| Year | Winnipeg | Rural Manitoba |
|---|---|---|
| 1962 | 10.4 | 7.5 |
| 63 | 10.6 | 7.4 |
| 64 | 10.8 | 7.7 |
| 65 | 11.0 | 7.7 |
| 66 | 10.9 | 7.6 |
| 67 | 10.7 | 7.8 |
| 68 | 10.8 | 7.7 |

The experience in Saskatchewan suggests the same relationship holds as in Manitoba. Roth's study showed that the average length of stay in the hospital was significantly shorter in rural areas which were less densely populated.

It has been the objective of this section to examine the variables which should be included in a predictive model of hospital utilization. It seems that the age, sex and urbanization factors are the most important factors determining the degree of hospital utilization in Manitoba. In the next section use of the age, sex factors will be made in order to develop the predictive model.

## 4.3 The analytical model

A model is a mathematical expression defining a functional relationship between a quantity that is to be explained to those elements that do the explaining. Thus the formulation of a hypothesis is the first step in the construction of a model. This hypothesis is to specify the theoretical relationships that are expected to exist. In turn this implies that a decision has to be made upon some measures to represent the theoretical variables and the collection of data for each of them. Having done this a mathematical relationship is set up. Generally one used the simplest relationship; a linear model, unless there is a reason to believe a more complex one is necessary.

As seen in the previous section it was found that the age and sex distribution of the population are the most important influences on hospital utilization in Manitoba. Correlating these variables with the population of Manitoba gives us the hypothesis. The model can then be written as follows -

$$y^i = \alpha + \beta x + e$$

where $x$ = population of Manitoba

$y^1$ = Total patient days for each of the eighteen diagnostic categories.

$y^2$ = Male patient days for each of the eighteen diagnostic categories.

$y^3$ = Female patient days for each of the eighteen diagnostic categories.

$y^4$ = Total separations for each of the eighteen diagnostic categories.

$y^5$ = Male separations for each of the eighteen diagnostic categories.

$y^6$ = Female separations for each of the eighteen diagnostic categories.

$e$ = error term.

It is usually assumed that the "e" value at each ( $x$, $y$) value are independent and normally distributed with a constant variance.

The eighteen diagnostic categories are:

1-) Infective and parasitic diseases.

2-) Neoplasms.

3-) Allergic, endocrine system: metabolic and nutritional diseases.

4-) Diseases of the blood and blood-forming organs.

5-) Mental, psychoneurotic and personality disorders.

6-) Diseases of nervous system and sense organs.

7-) Diseases of circulatory system.

8-) Diseases of respiratory system.

9-) Diseases of digestive system.

10-) Diseases of genito-urinary system.

11-) Deliveries and complications of pregnancy, childbirth and pueryserium.

12-) Diseases of skin and cellular tissue.

13-) Diseases of bone and organs of movement.

14-) Congenital malformations.

15-) Certain diseases of early infancy.

16-) Symptoms, senility and ill-defined conditions.

17-) Accidents, poisonings and violence.

18-) Supplementary classification for special admissions, livebirths and stillbirths.

Using least squares regression techniques parameters "$\alpha$" and "$\beta$" can then be estimated. Two measures can be used to determine whether the regression equations are significant or not.

One such measure is the sample correlation coefficient which measures the strength of the linear relationship between x and y. The coefficients estimate the change in the dependent variable for a unit change in the independent or explaining variables. The correlation coefficient is a relative measure with a range of $+1$ to $-1$. The greater the association of the variation in the dependent variable is to the variation in the independent variable, the closer the correlation will be to $\pm 1$. A correlation coefficient in the vicinity of zero would indicate no linear relationship, while a large negative coefficient would indicate a strong negative relationship.

Another measure is the F-test of significance. The F-test is a test of the null hypothesis $\beta = 0$ or of the null hypothesis that variation in X does not contribute to variation in Y. The question is whether the ratio of the explained variance to unexplained variance is sufficiently large to reject the hypothesis that Y is not linearly related to X.

Specifically, a test of the hypothesis

$$H_0 : \beta = 0$$

involves forming the ratio:

$$F = \frac{\text{Variance explained by regression}}{\text{Unexplained variance}}$$

or

$$= \frac{\hat{\beta}^2 \sum x_i^2}{s^2} \qquad \text{where } s^2 = \text{residual variance}$$

a 5% significant test involves finding the critical F value that leaves 5% of the distribution in the right-hand tail. If the sample F value calculated exceeds this, reject the null hypothesis and accept the alternate hypothesis. Namely, that variation in X does contribute to variation in Y.

A key issue in correlation analysis, the test of the null hypothesis;

$$H_o : \rho = 0 \qquad \rho = \text{correlation coefficient}$$

can be answered directly from regression analysis by testing the equivalent null hypothesis.

$$H_o : \beta = 0$$

Thus, rejection of $\beta = 0$ implies rejection of $\rho = 0$, and the conclusion that correlation does exist between X and Y. Therefore only F-tests were used in deciding whether a regression equation was significant or not.

4.4 Use of least-squares regression technique

In any study that uses regression analysis certain issues have to be dealt with when applying the technique. There has to be some rationale in using the technique with time series data. The choice of a regression line has to be made as to whether it is linear or curvelinear. The bias occurring from observational errors has to be accounted for and as well as any complications that arise due to simultaneous relationships.

The two main purposes of regression analysis are to estimate one variable given one or more explanatory variables or to assume some sort of casual explanation of one variable as a function of one or more other variables. In the first situation the idea is to make an estimate as accurate as possible, while in the second the regression is used to form a hypothetical explanation of the endogenous variables. In other words a theoretical model is evaluated from the regression analysis for the phenomenon under investigation. Most of the controversial issues about regression center about this situation. Furthermore this is the situation faced in this study namely, establishing a theoretical model from the regression relation.

In establishing the choice of a regression line many factors had to be taken into consideration. Is the regression line linear or curvilinear? One should use the simplest relationship, a linear model, unless there is a reason to believe a more complex one is necessary. Furthermore, similar studies in the United States[10] have shown that the results in using curvilinear relationships did not differ significantly from a linear relationship. Whether or not this holds for Manitoba can be seen by taking into account the data available. In previous sections the variables which were deemed unimportant were discarded, the result being the model in section 11, with one independent variable. Unless one tests for linearity one cannot assume that the relationships are linear. As stated earlier F-tests were conducted on the estimated regression equations. As will be seen in the following chapter, the F-tests indicate that there is no reason for believing that the relationships are not linear.

Another aspect that has to be looked into is observational error. Is the statistical data dealt with based on measurements that are exact? If not, the results may be spurious. Thus if the data is suspected or known to be unreliable because of systematic error, it is sometimes better not to use the data, because it is difficult if not impossible to extract results from unreliable data. As concerns the data from the Manitoba Health Services Commission, there is no reason to believe that the data are in error. The totals and subtotals of different tables within the data sheets lead to consistent results. This cursory check may not be 100% reliable but it does indicate that any observational errors will in all probability lead to results which may be at least consistent in their bias.

A problem that often arises when using time series data is that the disturbance terms are auto-correlated. If this occurs then the estimates of a & b in section 4.3 will still be unbiased in large samples but the variance of these estimates may be unduly large compared with estimates achievable by a slightly different method of estimation. The problem of using least-squares regression technique to obtain the variances of the regression coefficients, is that these variances will be seriously over-estimated. The result will be inefficient predictions in that the predictions will have needlessly large sampling variances. Certain tests have been developed, such as the Durbin-Watson d-statistic in order to test for the presence of auto-correlated errors, however such a test was not applied to the data, because the table for tabular values of the d-statistic has values only for sample sizes larger than 15. The sample size of 10 precluded the use of such a statistical procedure. One could also use covariance analysis to get rid of auto-correlation. This would entail removing a time covariate from x and y. The problem with this however is that it makes the results difficult to interpret.

Multicollinearity is also a problem which can arise when using either time series or cross-sectional data. This problem arises whenever any of the "explanatory variables are so highly correlated with one another that it becomes more difficult, if not impossible, to disentangle their separate influences and obtain a reasonably pricise estimate of their relative effects".[11] Fortunately we do not run across this problem in our analysis. Since there is only one explanatory variable it cannot be correlated with any other variable. However, both Y and X can be correlated with time, which may vitiate any causation statements. Because of correlations among the variables however, the conclusions from separate models cannot be interpreted independently. This is due to the fact that the independent variable is the same in all the models while the dependent variable changes from one model to the next.

Whether or not the study will be biased in any way due to the exclusion of simultaneous relationships cannot be determined. Only by developing and applying such a model could comparisons be made. As yet only one such model exists. Feldstein has constructed what he calls "An Aggregate Planning Model for the Health Sector" which involved a very complex model with nine endogenous variables and eleven predetermined variables. The system is solvable because it has nine equations as well as nine endogenous variables. However most of the equations and variables deal with the health system in England and this may make the model irrelevant for the situation in Canada or the

United States. Thus until such a model is developed for the situation in Manitoba and applied nothing can be said of the results with the exclusion of simultaneous relationships. Furthermore such a comprehensive model requires vast amounts of data which are either unavailable or would require extensive primary data collection. Such a model would probably run into problems of heteroscedascity, multicollinearity, as well as to which estimation procedure results in best linear unbiased estimators.

An important property of least-squares regression is that within the class of linear unbiased estimators of $\beta$ (or $\alpha$) the least squares estimator has minimum variance. Furthermore least squares regression works with a minimum of assumptions. Namely, that the probability function has the same variance $\sigma^2$ for all $X_i$'s and the random variable $Y_i$ are statistically independent.

In this section we have examined the properties of least-squares regression technique and have found it appropriate for estimation procedures. The next section will discuss the merits and the demerits of the model.

## 4.5 Merits and demerits of the model

One of the features of the hospital supply planning model as described above is the models ability to include relevant variables which are essential to the analysis. The existence of a medicare scheme in Manitoba results in relatively free access of all persons to hospital facilities thus rendering price differentials in medical treatment and the income distribution as rather insignificant elements in determining the demand for hospital facilities. The inclusion of the age and sex variables as related to the morbidity statistics are important indicators of present and future demand given changes in the population of rural and urban Manitoba.

In undertaking the study one of the major obstacles to using a more elaborate and comprehensive model was the availability of the data. Due to the small number of observations available it became increasingly important to restrict the number of variables in the relationships to be estimated. The inclusion of many explanatory variables would restrict the degree of freedom in the estimation procedures and may have subjected the estimates to large standard errors. As a result a less elaborate model was used, which yielded on the whole rather good results. Thus taking these factors into consideration the model thus provides one with a certain degree of confidence as to its effectiveness.

Had the data been available a more regionalized model could have been used as suggested in chapter two. This model could then take into consideration the flow of patients between hospital catchment areas and one could adjust the data accordingly. The advantages of using such a model have been discussed in previous chapters and will not be dwelt upon here. However taking into consideration all factors, the model that was used is in a sense "optimal" in that the financial resources needed to undertake more complex models were restrictive.

In the following chapter population projections will be made to 1976 and 1981. Using these projections and the model developed above the results of the model will be analyzed.

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# CHAPTER FIVE

## APPLICATION OF THE MODEL

### 5.1 Introduction

Having developed the predictive model in the last chapter, the present chapter will make use of the model for predicting the demand for hospital facilities in Manitoba for the years 1976 and 1981. However before this can be done, population projections to 1976 and 1981 have to be estimated. These population projections will be the main content of section one. The second section will then show the estimated demand for those years on hospital facilities. The measures of expected future utilization were: patient days and admissions. The last section will compare the present capacity of hospital facilities in terms of patient days, to the anticipated future capacity in the prediction years. This comparison will then indicate if there will be a shortage or a surplus of active treatment beds in Manitoba in those years.

### 5.2 Population projections for 1976 and 1981

In the last chapter the model developed utilized age, sex and diagnostic category morbidity information. In order to make projections, population information for the prediction years 1976 and 1981 were needed. The Metropolitan Corporation of Greater Winnipeg Population Study, 1961 to 1986 did not prove useful, since the information was not sufficiently disaggregated. Thus in order to circumvent this problem the estimated projections for the future population were arrived at as follows.

The method used for the population projections was of the age group transfer type, which resulted in the estimates in table 5.1. The data required was drawn from the Dominion Bureau of Statistics' national census report for 1956, 1961, and 1966, as well as from the yearly estimates of Manitoba's gross population as published in the Canadian Statistical Review. In the Dominion Bureau of Statistics' census reports the population breakdowns for each sex were given in five-year ranges. In order to derive the 1971 population estimates, each 1966 population count broken down into age and sex categories was transferred to the next highest grouping. The probable mortality factor was taken into account by adjusting each age category transfer by Manitoba life-table actuarial rates. This still left the 0-4 age category unaccounted for however. This category was estimated by adding the 1967 to mid-1970 Manitoba births and then extrapolating this trend linearly forward to 1971.

A further factor that had to be considered was that of migration of people into and out of the province. This was accounted for by using the age-category transfer method, duly life-table adjusted, for the years 1961 and 1966 and comparing these estimates with the actual population counts contained in the Dominion Bureau of Statistics' census reports. Any difference between the actual population counts and estimated age-category transfer totals were attributed to net migration.

Following this a ratio of the net migration total for each age category over the estimated population in each age category was calculated. If the resultant coefficient was positive this showed migration into the province, while a negative coefficient showed migration out of the province.

For each age category this procedure applied to 1961 and 1966 data made possible the derivation of a linear trend in the migration coefficients. The 1976 and 1981 estimates were then derived by adjusting the population transfers for the years 1971 and 1976. If there had been a past history of in-migration to Manitoba these estimates were scaled upwards while if the past history showed out-migration the estimates were scaled downwards. All problems had not been solved however. In using the age category transfer method the 0-4 age category disappeared. For 1971 the Canadian Statistical Review afforded the data required but there still remained the years of 1976 and 1981. In order to estimate the 0-4 age category for these future years, ratios of the actual population count in the 0-4 age category, over the accumulated total of females in the age categories of 20-40 were calculated for 1961, 1966 and 1971. The requisite information was then derived by applying the trend of these ratios against the accumulated female population estimates for the years 1976 and 1981.

Table 5.1 Population projections for Manitoba - 1976 and 1981

| | 1976 | | | 1981 | | |
|---|---|---|---|---|---|---|
| Age Category | Male | Female | Total | Male | Female | Total |
| 0 - 14 | 161,000 | 152,000 | 313,000 | 170,000 | 156,000 | 326,000 |
| 15 - 24 | 81,000 | 87,000 | 168,000 | 89,000 | 93,000 | 182,000 |
| 25 - 64 | 233,000 | 238,000 | 471,000 | 236,000 | 242,000 | 478,000 |
| - 65 | 32,000 | 39,000 | 71,000 | 42,000 | 48,000 | 90,000 |
| Totals | 507,000 | 516,000 | 1,023,000 | 537,000 | 540,000 | 1,076,000 |

In terms of population growth, estimates in table 5.1 indicate that Manitoba's population will increase at a rate of 1.17 percent per year between 1971 and 1976, and at a slower rate of growth of .98 percent per year between 1976 and 1981. The rural areas are expected to decline in both relative and absolute terms from between 1976 to 1981, at a rate of .20 percent per year. Metropolitan Winnipeg however is expected to grow at a rate of 1.66 percent per year between 1971 and 1976 as compared to 1.54 percent per year from 1976 and 1981.

One of the assumptions of any population projections is that the basis of future growth rates depends upon past population growth, namely the period from 1961 to 1971. In Manitoba's case, the projections reflect the decreasing importance of the agricultural sector and the resultant out-migration from rural areas into urban centres, especially Metropolitan Winnipeg. These estimates also take into consideration the net-migration trends of Manitoba during the period of 1961 and 1971 and their perpetuation into the future. Barring any radical changes in the social, economic and political fronts the figures in table 5.1 provide plausible population projections.

5.3 Estimates of demand in 1976 and 1981

Originally it was intended that estimates of demand in 1976 and 1981 would be disaggregated into various age groups. However as mentioned in the previous chapter F-tests were run to see whether or not the estimated regression equations were significant or not.

One-tailed F-tests were run at the 95% as well as 99% significance levels. At the 95% level any calculated F-statistic greater than 5.32 (the tabulated F-statistic for a sample size of 10) would result in the null hypothesis ($\beta = 0$) being rejected. This would mean that variation in X would contribute to variation in Y. If the calculated F-statistic was less than 5.32 then the null hypothesis ($\beta = 0$, namely that variation in X does not contribute to variation in Y) would be accepted and the estimated regression equation would prove to be of dubious value for predictive purposes.

Similar tests were run at the 99% significance level where the tabulated F-statistic for a sample size of 10 was 11.26.

It was found that for both patient days and admissions, which were broken down into various age-groups that the F-tests at both of the significance levels indicated that the null hypothesis should be accepted with the result that over 80% of the estimated regression equations proved to be of little predictive value. Since so many of the estimates proved to be of limited value no use was made of these figures. Instead the age groups were aggregated into one lump sum and regressed on patient days and admissions. Nearly all the estimated regression equations turned out to be significant at the 99% level of significance. This can be verified by looking at tables 5.3 and 5.4 under the column F-statistic. Since these estimates were proven to be useful they were used to make point estimates for 1976 and 1981. As well, confidence intervals were calculated for each of the future predictions.

In order to construct proper confidence intervals for each predicted value, it was necessary to assign a variance appropriate to each value rather than simply to quote a mean predicted value. This is done by increasing the variance of the estimate of the mean by the variation for individual values.

Thus the variance of a predicted Y is -

$$S_{YX}^2 = S_{yx}^2 \left( 1 + \frac{1}{n} + \frac{(X - \bar{\bar{x}})^2}{\leq (x - \bar{x})^2} \right) S_{yx}^2 = \frac{\leq y^2 - a \leq y - b \leq xy}{n - 2}$$

where $S_{yx}^2$ is the residual variance about the regression line of y on x and X if the predicted value, namely 1,023,000 for 1976 and 1,076,000 for 1981.[1]

For 1976:

$$S_{YX}^2 = S_{yx}^2 \quad (1.950)$$

For 1981:

$$S_{YX}^2 = S_{yx}^2 \quad (3.395)$$

The 99% confidence intervals were calculated as follows:

$$(a+bx) \pm 3.36 \sqrt{S_{YX}^2}$$

The confidence intervals for each diagnostic category can be seen in tables 5.4 and 5.5 Table 5.2 gives the names of each diagnostic category.

Table 5.2 16 diagnostic categories[2]

1. Infective and parasitic diseases.
2. Neoplasms.
3. Allergic, endocrine system, metabolic and nutrional diseases.
4. Diseases of blood and blood forming organs.
5. Mental, psychoneurotic and personality.disorder.
6. Diseases of the nervous system and the sense organs.
7. Diseases of the circulatory system.
8. Diseases of the respiratory system.
9. Diseases of the digestive system.
10. Diseases of the genito-urinary system.
11. Deliveries and complications of pregnancy, childbirth and pueryserium.
12. Diseases of the skin and subcutaneous.tissue.
13. Diseases of the bones and the organs of movement.
14. Congenital malformations.
15. Accidents, poisonings and violence (including late effects).
16. Other specified and ill-defined diseases.

Table 5.3 Actual demand on all public General Hospitals in Manitoba for 1970 and estimated demand for 1976 and 1981.

| | | | 1976 Estimates | | | 1981 Estimated | | |
|---|---|---|---|---|---|---|---|---|
| Demand Measure | Actual 1970 | F Statistic | Point Estimated | Lower Limit* | Upper Limit* | Point Estimate | Lower Limit* | Upper Limit |
| Total Patient Days | 1,923,684 | 433.2 | 2,065,000 | 1,981,000 | 2,150,000 | 2,287,000 | 2,179,000 | 2,394,000 |
| Total Admis. | 178,694 | 98.2 | 178,000 | 170,000 | 187,000 | 189,000 | 179,000 | 199,000 |

* These are lower and upper 99% confidence intervals.

5.3.1 Patient day estimates:

From 1961 to 1968 it was found that the number of patient days experienced in all of Manitoba's public general and extended care facilities increased from 1.602 million to 1.830 million, which is an annual compounded rate of 1.65 percent. It can well be expected that with Manitoba's population expected increase in population from 982.0 thousand in 1971 to over 1.070 million by 1981, and assuming that the populations in 1976 and 1981, would be given the same access to hospital facilities as of the populations in 1961 through 1969 it can be assumed that the demand for public general and extended care facilities would also rise in proportionate order. This however is not strictly true because morbidity depends in part, on the age distribution which is changing. The patient day estimates were then derived by using the population projections in table 5.1 and applying them to the model developed in the last chapter, and re-adjusting the totals to account for out-of-province patient days.

On the basis of the method developed in the last chapter it was found that the total estimated patient day demands for 1976 would be 2.065 million, increasing to 2.287 million in 1981, as seen in table 5.3. The 99% confidence intervals for the point estimates of 1976 and 1981 were respectively (1.98 mil., 2.150 mil.) and (2.179 mil., 2.394 mil.) comparing the point estimate as well as the confidence intervals with actual 1970 data of total patient days of 1,923,684, we see that this figure does not fall within the confidence

Table 5.4 Actual total patient day demands on all public General Hospital in Manitoba for 1970 by diagnostic category and estimated patient day demands for 1976 and 1981.

| Diagnostic Category | Actual 1970 Data | F Statistic | 1976 Estimates Point Estimate | 1976 Estimates Lower Limit* | 1976 Estimates Upper Limit* | 1981 Estimates Point Estimate | 1981 Estimates Lower Limit* | 1981 Estimates Upper Limit* |
|---|---|---|---|---|---|---|---|---|
| 1 | 72,163 | 1.5 | --- | --- | --- | --- | --- | --- |
| 2 | 177,412 | 161.9** | 201,000 | 184,000 | 217,000 | 228,000 | 206,000 | 250,000 |
| 3 | 46,157 | 15.6** | 72,000 | 52,000 | 93,000 | 84,000 | 58,000 | 110,000 |
| 4 | 12,136 | 39.0** | 17,000 | 13,000 | 21,000 | 20,000 | 15,000 | 26,000 |
| 5 | 105,047 | 100.1** | 87,000 | 72,000 | 101,000 | 106,000 | 87,000 | 125,000 |
| 6 | 143,081 | 116.2** | 326,000 | 255,000 | 397,000 | 422,000 | 332,000 | 512,000 |
| 7 | 316,246 | 261.1** | 311,000 | 278,000 | 346,000 | 383,000 | 338,000 | 428,000 |
| 8 | 200,077 | 3.3 | | | | | | |
| 9 | 190,299 | 11.1** | 206,000 | 184,000 | 228,000 | 216,000 | 184,000 | 248,000 |
| 10 | 107,281 | 63.1** | 137,000 | 108,000 | 166,000 | 165,000 | 128,000 | 202,000 |
| 11 | 129,122 | 12.3** | 111,000 | 54,000 | 170,000 | 86,000 | 12,000 | 159,000 |
| 12 | 29,253 | 20.5** | 24,000 | 17,000 | 31,000 | 20,000 | 11,000 | 28,000 |
| 13 | 111,088 | 117.8** | 129,000 | 112,000 | 146,000 | 152,000 | 131,000 | 174,000 |
| 14 | 16,645 | 1.7 | --- | --- | --- | --- | --- | --- |
| 15 | 229,371 | 139.0** | 239,000 | 210,000 | 268,000 | 282,000 | 245,000 | 320,000 |
| 16 | 38,306 | 25.9** | 90,000 | 77,000 | 103,000 | 116,000 | 109,000 | 132,000 |

** significant at 99% level
* limits give 99% confidence interval

intervals of either the 1976 or 1981 estimates. From this we can infer that the increase in total patient day demands in 1976 and 1981 is a significant increase.

Table 5.4 contains information as to actual patient day demands on all public general hospitals in Manitoba for 1970 by diagnostic category as well as estimated patient day demands for 1976 and 1981 by diagnostic category. Diagnostic categories. 1. Infective and Parasitic Diseases and 14. Congenital malformations contain no estimates because these categories failed the F-test. Thus estimates would have been of dubious value.

Comparing the actual data for 1970 with the estimates and confidence intervals for 1976 and 1981 it can be seen that the confidence intervals for the 1976 estimates encompass the 1970 figure for the following categories; 5. Mental, Psychoneurotic and Personality Disorder. 9. Diseases of the Digestive System. 11. Deliveries and Complications of Pregnancy, Childbirth and Pueryserium. 7. Diseases of the Circulatory System. 12. Diseases of the Skin and Subcutaneous Tissue and 15. Accidents, Poisonings and Violence. Examining the point estimates for each of these categories it can be seen that the point estimates for 1976 are all lower than the 1970 figures. These decreases may be the result of a shifting away of these cases from the hospital to out-patient departments. For mental, psychoneurotic and personality disorder it may indicate that these people are being placed in appropriate facilities rather than active treatment hospitals.

The 1981 confidence intervals encompass the 1970 figures for categories 5, 9, 11 and 12. The point estimates for category 5 and 9 show small increases in demand for patient days for these cases, but not significant increases. Category 11, Deliveries and Complications of Pregnancy continues to show a decrease in the point estimate. This may be a result of technical advance in this area which decreases the chances of complications. Category 12, Diseases of the Skin and Subcutaneous Tissue shows quite a decrease as indicated by the point estimate for 1981. The upper bound of the confidence interval is lower than the 1970 figure. Thus it can be expected that cases of this type to decrease in the coming decade.

The decrease or the small increase that is expected in the demand for future patient days of the diagnostic categories discussed above means that present facilities for the treatment of these particular illnesses seem to be sufficient until 1981, in spite of a growing population.

Table 5.5 Actual total hospital admissions for all public general hospitals in Manitoba for 1970 by diagnostic category and estimated admissions for 1976 and 1981.

| Diagnostic Category | Actual 1970 Data | F Statistic | 1976 Estimates Point Estimate | 1976 Estimates Lower Limit* | 1976 Estimates Upper Limit* | 1981 Estimates Point Estimate | 1981 Estimates Lower Limit* | 1981 Estimates Upper Limit* |
|---|---|---|---|---|---|---|---|---|
| 1 | 7,557 | 8.1 | 3,900 | 2,700 | 5,100 | 4,000 | 2,700 | 5,900 |
| 2 | 9,771 | 48.0 | 10,400 | 9,000 | 11,700 | 11,600 | 9,800 | 13,300 |
| 3 | 3,067 | 26.7 | 5,000 | 4,100 | 6,000 | 5,700 | 4,500 | 6,800 |
| 4 | 1,347 | 118.8 | 1,200 | 1,000 | 1,400 | 1,500 | 1,200 | 1,800 |
| 5 | 5,998 | 80.3 | 6,000 | 4,700 | 7,500 | 7,700 | 5,800 | 9,500 |
| 6 | 6,716 | 168.7 | 12,600 | 10,800 | 14,300 | 15,500 | 13,100 | 17,800 |
| 7 | 17,188 | 174.6 | 18,400 | 15,900 | 20,900 | 22,600 | 19,400 | 25,800 |
| 8 | 29,902 | 13.1 | 30,100 | 23,000 | 37,100 | 31,600 | 22,800 | 40,400 |
| 9 | 21,094 | 17.8 | 23,500 | 21,300 | 25,800 | 24,700 | 21,800 | 27,600 |
| 10 | 13,015 | 65.5 | 15,400 | 12,100 | 18,700 | 18,800 | 14,600 | 23,000 |
| 11 | 24,819 | 6.8 | 21,500 | 10,200 | 32,700 | 17,900 | 3,900 | 3,900 |
| 12 | 3,530 | 25.6 | 2,900 | 2,500 | 3,400 | 2,600 | 2,000 | 3,100 |
| 13 | 6,430 | 92.2 | 6,600 | 5,900 | 7,200 | 7,300 | 6,500 | 8,100 |
| 14 | 1,653 | .1 | --- | --- | --- | --- | --- | --- |
| 15 | 19,787 | 273.7 | 18,400 | 17,300 | 19,400 | 20,000 | 18,800 | 20,200 |
| 16 | 6,820 | 17.1 | 12,100 | 11,800 | 13,300 | 14,200 | 12,600 | 15,800 |

* limits give 99% confidence interval

### 5.3.2 Patient admission estimates

Carrying out similar estimates for expected admissions, total admissions were predicted to increase to 178.0 thousand in 1976, with a subsequent increase in 1981 to 189.0 thousand. The 99% confidence intervals for these point estimates were (170,000: 187,000) for 1976 and (189,000; 199,000) for 1981 as shown in table 5.3. The 1976 estimate is not a significant increase in patient admissions because the 1970 admissions were 178,694 and this figure falls within the prediction interval. The 1981 estimated figure however is significant. The 1976 estimate seems to indicate that present facilities would be adequate at least until 1976.

Looking at table 5.5 under the 1976 estimates it can be seen that the 1970 figure falls within the confidence interval for the following categories: 1, 2, 4, 5, 7, 8, 10, 11, 12, 13, 15. The point estimates for categories 1, 4, 12 and 15 are lower than the 1970 figure. For categories 4, 12 and 15 the upper bound is lower than the 1970 figure. This indicates a significant decrease in admissions for these particular illnesses. In the rest of the categories the increase in admissions is negligible. Coupling this with the aggregate estimated figure for 1976, it follows that if the total increase in admissions is not significant for the whole, then it is expected to be the same for its components.

In 1981 it can be seen that the 1970 figure falls within the confidence intervals for categories 1, 4, 5, 8, 11 and 15. The point estimate for category 1, has increased from the point estimate of 1976 by 100 admissions but this does not represent a significant increase. It is still significantly lower than the 1970 figure because its upper bound is still lower than the 1970 figure. The point estimate for category 11 has decreased from both the 1970 figure as well as the 1976 estimates. This indicates a significant decrease in the admissions to hospitals for complications of pregnancies and related problems.

For the rest of the diagnostic categories, namely 4, 5, 8 and 15 there is an indication that there will be no significant increase in admissions for these particular illnesses. Thus present facilities for the illnesses may be sufficient even to 1981.

Thus it seems that present facilities can accommodate the patient admissions to hospitals at least until 1976. New facilities however may have to be constructed for the expected increase in admissions in 1981.

**Table 5.6** Average length of stay for 1971 and estimates of average length of stay for 1976 and 1981.

| Diagnostic category | 1970 | 1976 | 1981 |
|---|---|---|---|
| 1 | 9.5 | — | — |
| 2 | 18.2 | 19.4 | 19.7 |
| 3 | 15.1 | 14.3 | 18.7 |
| 4 | 8.9 | 16.7 | 13.3 |
| 5 | 17.5 | 14.1 | 11.5 |
| 6 | 21.3 | 26.0 | 27.3 |
| 7 | 18.4 | 19.5 | 17.0 |
| 8 | 6.7 | 7.6 | 6.5 |
| 9 | 9.0 | 9.7 | 8.7 |
| 10 | 8.2 | 8.9 | 8.8 |
| 11 | 5.2 | 5.2 | 4.8 |
| 12 | 8.3 | 8.0 | 7.6 |
| 13 | 17.2 | 19.6 | 20.8 |
| 14 | 10.1 | — | — |
| 15 | 11.6 | 13.0 | 14.0 |
| 16 | 5.6 | 12.7 | 12.7 |
| TOTAL | 10.8 | 11.6 | 12.1 |

5.3.3 Average lengths of stay:

The average lengths of stay figures, in table 5.6, are derived from patient day and admission estimates of tables 5.4 and 5.5. (Patient days / Admissions = Average length of stay) These figures should not be taken as exact because they are based upon estimates which have upper and lower limits.

It can be seen from table 5.6 that the average lengths of stay in nearly all categories is expected to increase from 1976 to 1981. The over-all average length of stay increases from 10.8 days in 1970 to 11.6 and 12.1 days in 1976 and 1981. This is due to patient day demands increasing more sharply than admissions; which may reflect the effect of a population with an average age which is expected to be older than the present population. An older population can be expected to increase the average length of stay figures, because it is a fact that elderly people have longer stays in hospitals than their younger counterparts.

5.4 Comparisons of present capacity and expected future capacity

This section will undertake to examine the present hospital treatment capacity in Manitoba, and relate this capacity to the expected patient day forecasts in the previous section. In doing so, it will be found whether Manitoba will be deficient or not in hospital facilities in the years 1976 and 1981.

The rated bed capacity of all public general hospitals as of January, 1971 was 5, 981 rated beds. Translating these into patient day capacity (5,981 x 365 days = 2,183,065) the potential patient day capacity is 2,183,065. Assuming an eighty percent occupancy rate, the number of patient days that could reasonably be expected to be serviced by the rated bed capacity is 1,746,452. The rated bed capacity of extended care treatment as of January, 1971 was 841 beds. This capacity generates a potential patient day capacity of (841 x 365 = 306,965) at 100% occupancy rate. However, assuming an occupancy level of 87% (which is an average occupancy level for extended care hospitals in Manitoba), 245,572 patient days can reasonably be expected.

Given the previous patterns of percentage occupancy the total number of active treatment and extended care patient days that the existing system can reasonably service is 1.992 million patient days. However, the patient day demands upon the hospital system are expected to total 2.065 million in 1976 and 2.287 million in 1981 (table 5.3) leaving a level of excess demand of .730 million patient days in 1976 and .295 million patient days in 1981. The confidence interval for 1976 suggests that there is a 99% probability that the actual excess demand falls between 1.0 thousand to 158.0 thousand patient days. In 1981 the prediction intervals for the excess demand is 179.0 thousand to 413.0 thousand patient days.

Assuming, the unchanged total rated bed capacity of 6,822 beds as of January 1971, any increase in hospital facilities will tend to decrease the excess of demand over supply through its influence on supply.

Converting these estimates of additional beds needed to satisfy expected demand in 1976 and 1981 into bed capacities, the Manitoba hospital system would require in 1976

(73,000 ÷ 365 = 200) additional beds and

(295,000 ÷ 365 = 808) additional beds in 1981

This of course, assumes that people in 1976 and 1981 are given the same access to hospital care as the population in the trend analysis of 1961 to 1969.

From the prediction intervals of table 5.3 we can constrict upper and lower bounds for the number of extra beds needed in 1976 and 1981. In 1976 the lower bound is an extra 4 beds while the upper bound is an extra 400 beds. In 1981 the lower bound is 480 extra beds while the upper bound is 1,130 extra beds. Considering that the lower and upper bounds as to the extra beds needed for 1976 are 4 beds and 400 beds respectively, as well as the fact that the expected increase in patient admissions to 1976 is not significant, the conclusion warranted is that at least until 1976, present hospital facilities could accomodate the population of Manitoba until 1976. However new facilities would have to be built for 1981 considering the bounds (480; 1,130) as well as the expected increase in patient admissions which is significant.

However if Manitoba were to adopt the adequacy standards of the American Hill-Burton programme which would dictate a bed per 1000 population ratio of 5.0, Manitoba would have more than adequate facilities until 1981. The bed-population ratio without any new facilities for 1976 is 5.8 beds per 1000 population, while in 1981 the bed-population ratio is 5.6 beds per 1000 population. Thus with these standards Manitoba has a more than adequate supply of hospital beds.

However if Manitoba residents wish to maintain the present level of accessibility to hospitals as in the 1961 to 1969 period the supply of hospital beds must be increased. Assuming that the method of delivery of health care does not change. However, an increase in the supply of hospitals is not necessarily concomitant with an increase or maintenance of a certain standard of medical care. The provision of appropriate ambulatory care services may maintain the same level of medical care without the costly expenditures involved in building new hospital facilities.

Footnotes:

1. These and other formulas given in this section may be found in any standard statistical text: see for example, R. G. D. Steele and J. H. Torrie, Principles and Procedures of Statistics, McGraw-Hill, New York, 1960, Chapter 9.

2. These diagnostic categories are those in the International Classification of Diseases, 8th revision.

3. These figures exclude patient day estimates of federal and contract hospitals, as well as the Shriner's Hospital in Winnipeg.

# CHAPTER SIX

## SUMMARY AND CONCLUSIONS

The purpose of this study has been to analyze various hospital bed supply planning models and to determine which model would be the most appropriate for planning purposes taking into consideration their relative merits and demerits. Having done this one model was chosen and estimates of future bed requirements were undertaken. The model chosen however, was not the one which the previous analysis indicated as to being the best. Such factors as time and cost constraints involved, precluded the use of the best method. Thus in a sense, the model which was used is the "best" considering the financial resources available.

The uniform bed-population ratio as well as the bed-death ratio were both rejected on the grounds that these ratios generalize across non-homogenous segments of the population. Two communities of identical population size will rarely demand the same number of beds per 1000 of population due to various socio-economic factors. Furthermore such ratios implicitly assume that all hospital beds whether rural or urban are used in the same manners.

Queuing theory models have been critized because demand is not an independent variable but rather a function of the supply and the length of queue. The result then of using this method is that the supply of hospital beds for the current period in an area is the correct number for the current period as estimated by the model.

Demand model analysis as well as pressure index demand analysis both suffer from the problem that beds provided in an area cannot be determined on the basis of manifest demand. If the level of supply in each area were increased, the parameters of the demand equation would change, indicating higher levels of predicted demand. The omission of bed supply from the demand (bed use) equations could be a serious misspecification that may have sizable effects on lack of the regression coefficients. Furthermore systems which deal with more than one explanatory variable should have more attention paid to the effects of interactions among the variables such as joint dependencies of the variables.

The one model which didn't display the disadvantages of the previous ones was the Multiregional Patient Flow Model. This particular method can measure how much hospital care is being used by the population of each geographical area as well as where the patients from each community go for their care. The model is also adopted to making projections of expected future demand on hospital facilities.

However in spite of its merits the implementation of this technique requires a large amount of financial resources in order to gather the data required. Namely, a major study would be needed. Thus one has to opt for another technique which has been previously shown in chapter 4. This particular method has been used because it proved impossible to disentangle the relationships between "need" and "demand" for medical care. This is a difficult situation to be in due to the characteristics of the system. In any hospital system where doctors are paid fees in terms of the patient days their patients utilize while in the hospital, there is an obvious bias towards a higher level of demand for medical care than is warranted by the real needs of the patients. This behaviour may account for the high social participation and the relatively high ratio of beds per 1000 of population in Manitoba. Thus the results of using morbidity data to establish trends from the period of 1961 to 1969 and extrapolating these to 1976 and 1981 implicitly assumes that the population of 1976 and 1981 will be given the same access to hospital facilities as the population of 1961 to 1969. The planning model thus gave the results of patient days and admissions in chapter 5.

However basing estimates upon past manifestations of demand may result in problems. The study seemed to indicate that supply did not have affect the demand for hospital facilities to any great extent. However, this may be somewhat misleading due to the bias of medical doctors' towards hospitalizing patients. Hospital administrators attempt to operate their hospitals efficiently. Any bed left unoccupied other than beds used for emergency purposes is a waste and resources and pressures exist in filling any available space. This bias towards maximum utilization of existing facilities may mean that as soon as hospital facilities are built, there is tremendous pressure in utilizing these facilities. Thus the supply of hospital facilities may very well generate the demand needed to fill the vacancies due to pressure by hospital administrators and medical doctors.

In spite of some of these problems; through the assumptions of projection and the relationships of demographic factors to hospital admission, an attempt was made at estimating future hospital requirements expected to prevail in 1981.

In comparing the results it was found that either additional hospital beds would be required or the provision of alternatives to hospital care would be needed in 1981 to ensure that future population the same level of health care that exists in Manitoba today.

Now, the immediate response of many medical doctors, hospital administrators and citizens when forced with the conclusions of chapter 5, namely the possibility of a bed shortage is to clamour for additional active treatment beds. However, active treatment hospital facilities are the most costly to construct, the most difficult to staff, and the most expensive to maintain. Despite these facts, present hospital systems are still heavily biased in favour of this type of health care facility. Between the years 1955 and 1968 public and private expenditures on hospital care increased at the rate of 11.3 percent per year. In 1968, fifty six percent of all public and private health expenditures in Canada was spent on hospital care, with hospital care accounting for seventy-eight percent of total government spending on health. Furthermore over eighty percent of total expenditures on health care were expenditures on active treatment hospitals. Because of budgetary constraints governments have made it a deliberate policy either to limit the construction of active treatment beds or to examine the feasibility of utilizing alternatives to this costly facility.

Taking into consideration the high cost of this method of medical treatment and the fact that by any criterion of bed adequacy Manitoba already has sufficient active treatment beds and would continue to have so until 1981, the conclusion seems to be that an alternative method of medical treatment should be provided. Such an alternative could be in the form of ambulatory care. If such a program was implemented care would have to be taken so that Manitoba maintains its high level of medical care.

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