A MATHEMATICAL MODEL FOR ANALYSIS OF RURAL HEALTH CARE SYSTEMS

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1972

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1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1977

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RURAL HEALTH CARE SYSTEMS

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ACKNOWLEDGMENTS

I wish to express my sincere appreciation to my adviser, Dr. Gerald A. Doeksen, for his encouragement and assistance and his faith in my ability to work independently, all of which made my years at Oklahoma State particularly valuable for me. I also wish to thank my committee, Dr. Marc A. Johnson, Dr. Luther G. Tweeten, and Dr. Lyle D. Broemeling, for their valuable assistance in the preparation of the final manuscript.

I wish to thank Dr. Bernal L. Green and Dr. Ivan R. Hanson for their assistance in the early formulation of the problem and in finding the data. Appreciation is also extended to Mr. Alan May for his efforts in gathering data.

Dr. Karen Van Wagner, Mr. Louis M. Stackler and Mr. Jack Boyd are due thanks for their assistance in gathering information and insights concerning health decision processes.

Appreciation is extended to Dr. James S. Plaxico and the Department of Agricultural Economics for their financial assistance and interest in research in health economics.

Special thanks is extended to Mrs. Vicki Melton, Mrs. Karina Flynn and Mrs. Nancy Newby for their typing of the rough draft and Mrs. Linda Howard for her typing of the final draft.

Finally, special gratitude is extended to my parents, whose love, encouragement, support, and strong belief in the value of a graduate education made this all possible. I gratefully dedicate this dissertation to them.

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CHAPTER I

INTRODUCTION

Need for the Study

Since 1946, with passage of the Hill-Burton Act, health planning at the state and substate level has been required by law. The National Health Planning and Resource Development Act (PL 93-641) is a recent act (1974) designed to provide health planning in all areas. This act designates the creation of health systems agencies, which are responsible for establishment and implementation of a health system plan and to approve certain grants and contracts.

This legislation reveals federal awareness that impacts of health investment decisions extend beyond the local level. To expand planning beyond the local level implies that health care actions are part of a regional health system. Individual health care decisions involve several health services, both independently and in combinations. Interactions occur between different locations and between different service types. Intuitively, therefore, a method of modeling a health care system to include these interactions is needed.

This intuitive need exists in fact. Health planners in Oklahoma have expressed interest in both a model such as this and the information necessary to create such a model. This interest is on two levels. On a statewide basis the interest is on estimating demand for services on a local level and the distribution of these demanders between alternative suppliers. On the local and substate level interest is in estimating the demand for services and estimating the cost of supplying such services. Therefore, the value of the study from a health planner's viewpoint is twofold. The underlying data base is valuable because much of this information is unavailable elsewhere. The total model is valuable because it combines many of the factors important in a regional health care system into a single analysis.

Objectives

The primary objective of this research is to develop a model for a regional health care system which includes several services, spatial and monetary dimensions, and allows comparison of several goals. Secondary objectives are:

1. To develop a data base for empirical, population-based, health planning;

2. To develop capital and operating budgets for several types of health facilities for a rural area;

3. To compare the effect of different objectives for the health system;

4. To forecast future performance of the regional health system for the study area;

5. To determine the feasibility of new facilities; and

6. To examine methodological problems with using the model.

The Study Area

In order to test the model in a specific situation, the northwest portion of Oklahoma is used for the study area. This region, shown in

Figure 1, consists of 16 counties which had a 1970 population of 230,892. Of these 121,727, or 52.7 percent, lived in communities with populations exceeding 2,500, and 69,948, or 30.2 percent, lived in Enid and Ponca City--the two cities larger than 10,000. Garfield and Kay counties, in which these cities lie, are the only counties with populations larger than 20,000, having 45.1 percent of the region's population. The region has 24 hospitals, one just recently reopened, 24 emergency rooms, 38 ambulance services and 37 towns with at least one physician. Of the 24 hospitals in the area, only five have more than 100 beds, three of these being in Enid.

Organization of the Study

The objectives will be met using a three step procedure. The first step is the conceptual development of the whole and the parts of a health care system. This is presented in Chapter II. Next, this conceptual system is translated into a functional model, with the data necessary for its use presented. Chapter III contains this model development. The third step is testing the model in various situations to evaluate its strengths, weaknesses, and the intricacies in its use. Chapter IV presents a simulation of the 1975 health care system for the study so that the model's performance may be compared to a known situation. Chapter V contains estimates of future system performance, as the model is used for the years 1980, 1985, 1990 and 1995. Chapter VI examines certain methodological problems, as sensitivity to various types of error are examined. Summary, conclusions, implications, and limitations are contained in Chapter VII.

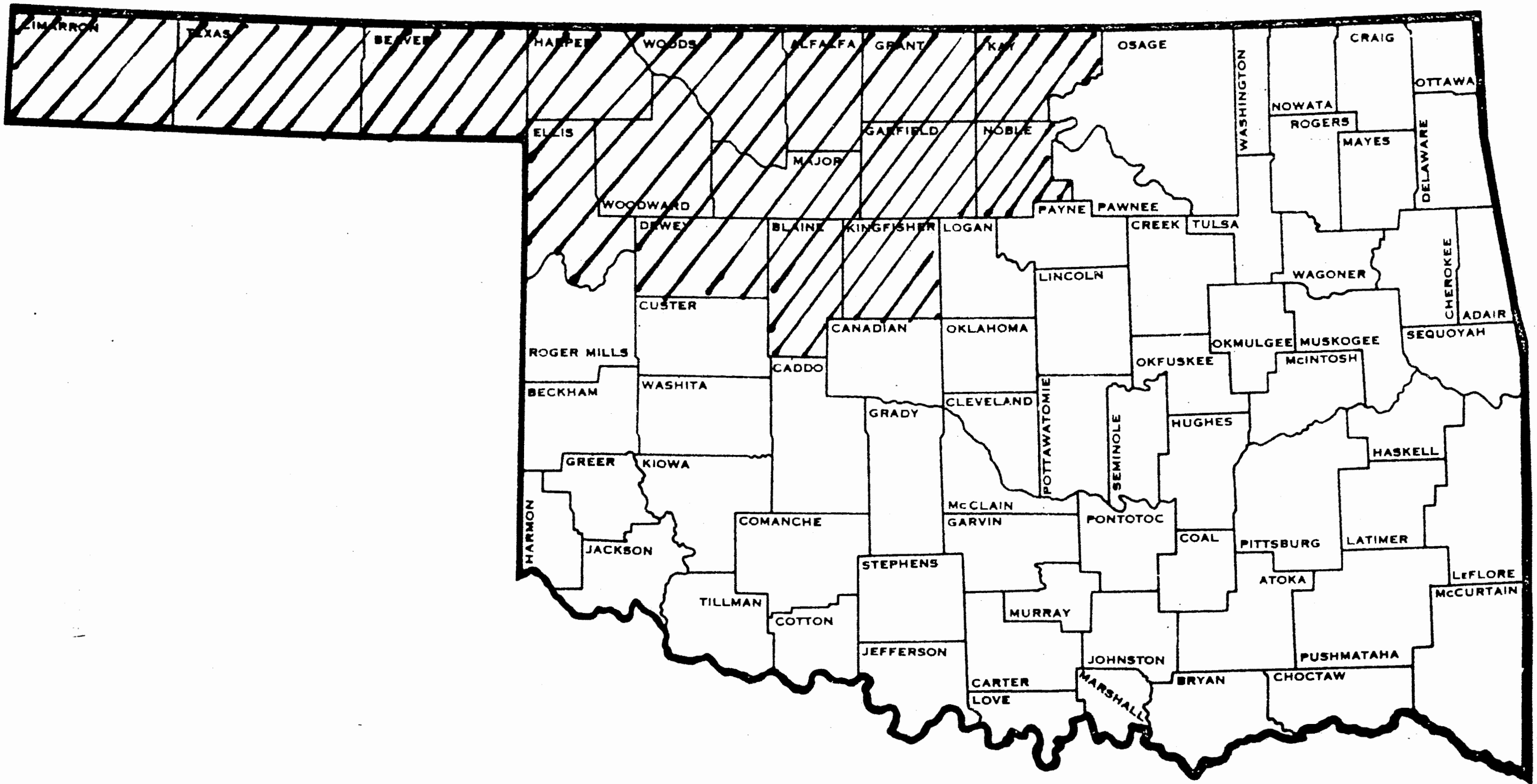


Figure 1. Map of Oklahoma Showing the Area of the Study

CHAPTER II

REVIEW OF LITERATURE

A comprehensive representation of a system requires consideration of the problem both in its entirety and of its component parts. This entails a search of the literature in a different manner than required for a more compact problem. The size of the whole forces some simplification in the treatment of individual parts from the complex approaches possible in a more limited study. This simplification implies the existence of studies more advanced than desired or required in the broader perspective. Accordingly the literature review which follows examines alternative approaches for each part of the system and attempts to extract the important characteristics necessary for adequate treatment of this part. Similar procedures are followed for health systems as a whole.

The theoretical and empirical literature are discussed separately to allow greater continuity in the presentation. The theoretical development of the model will be handled in three parts. First, the demand for health care is treated. Second, the supply of health care is discussed, concentrating on individual decision units. Third, spatial considerations are considered along with the theory underlying regional or other health systems. The supporting empirical literature is reviewed finally in subsets generally consistent with the general divisions of the theoretical portion.

It should be noted initially that the divisions are largely artificial, selected on the basis of apparent consistency with the final model's divisions and on the basis of divisions in the literature itself.

The Demand for Health Care

The theory of consumer behavior explains an individual's expenditures as a utility maximization process. The accuracy of the relationships derived using the theory of consumer behavior depends upon the accuracy of the underlying assumptions. Obviously, real people are not always rational and do not always know all the information pertinent to their decision. The demand for health care is a consumer choice situation where the inaccuracy of the assumptions lends special characteristics to the effect of prices and income. Much of the interesting literature is concerned with what digressions from the demand for an ordinary good occur and why.

When analyzing the medical services market, partially subsidized, and third party payment for medical care instill an element of confusion because time costs tend to be substituted for direct costs. In light of the dual cost character of consumption of health care, Holtmann (1972) develops a utility maximization model and examines some of the interrelationships. Using a two good model, where consumption requires time and money, and work requires time and earns money, he shows the equilibrium is affected by both time and money costs. Further, analysis of this model reveals that higher paid persons would consume more costly, less time consuming types of health services, while poorer individuals substitute time for expense, and as the price of a commodity rises, those services using much of it are de-emphasized.

Acton (1975) develops a similar model and draws some additional implications. These are that as the direct cost of a service declines, either through insurance or some subsidy mechanism, the role of non-monetary factors such as time costs increase. This general hypothesis is tested by estimation of certain elasticities. These elasticities support formulation of a model with differentiation between earned and non-earned income and between money costs and time costs.

Phelps and Newhouse (1974) relate this model to the concept of co-insurance, i.e., insurance where the recipient shares the risk. Considering the total cost of health care as perceived by the recipient to be the time cost plus the patient's share of the money costs, the authors derive the elasticities of demand for health care with respect to the co-insurance rate and with respect to time. Estimating these elasticities, they find demand to be quite inelastic, yet non-zero, and to vary according to the service in question.

The factors influencing the demand for health care are examined by Joseph (1971) with special interest paid to problems relating to their empirical evaluation. The effect on the quantity demanded of health care of changes in its price are found to be small, with less sensitivity found in patients having more serious conditions. Although income changes affect the demand for health care, its elasticity is less than one.

While references cited to this point concentrate on economic variables, much emphasis is given to the effect of other factors, included only implicitly in the consumer behavior model. An example of this is Leveson (1970), who separates different determinants of demand for medical care in general, and in ambulatory medical care, in particular. Concentrating on factors generally omitted from econometric estimation of demand, the types of relationships which have been found to exist are described and then alternative rationales for such behavior, and their implication on policy decisions concerning free care are hypothesized. Factors discussed are social benefits, the role of health in medical care demand, the role of education, the role of information, and the determinants of choice between alternative sources of medical care. It is apparent that some of these factors are included in the evolution of the tastes and preferences underlying the utility function, especially the role of education, the role of health, and some of the determinants of choice between alternatives. Social benefits are a source of market failure in the sovereign consumer model and are partially overcome by the intervention of government. The last factor, the role of information, is a deficiency in the underlying assumptions in the theory of consumer choice. The importance of information is a major impediment in communication between economists and health decision makers, and accordingly merits more careful examination.

Weiss and Greenlick (1970), in an analysis of usage patterns of a prepaid group medical plan, find the method of initial contact with the health care system to be related to social class. In a study related to the later section of spatial considerations, Morrill, Erickson and Rees (1970) address themselves to the demand for health care. Socio-economic factors influencing hospital choice are race, religion, and income. All hospitals are not equally receptive to minority groups and low income patients. Additionally, when a hospital operated by a religious denomination is available, patients of that denomination often prefer to go there. These factors imply that the apparent economic choices are not always as they appear.

Formal development of a utility maximization model is unnecessary given the inflexibility of the solution method. However, a brief discussion of the factors affecting the demand for health services is warranted and, hence, is included below.

The quantity demanded of a health service is assumed to be inversely related to its price. This relationship is not strong, i.e., the demand is inelastic, because health services are usually necessities, substitutes are few, and there is little autonomy for the consumer in treatment choice. Some substitutability does exist between alternative forms of health care, with the cross price elasticities being greater for ailments of a less serious nature. All such elasticities are small, however.

Since health care is a normal good, as incomes increase health care expenditures should increase also. However, income and the state of one's health are not independent, with needy people often having ill health due to dietary considerations, poor living conditions, and other factors. The involuntary health expenditures for a poor person may be higher than for his wealthier counterpart, with a wealthy person having higher discretionary health purchases. The net effect of income on the demand for health care is generally considered to be a u-shaped function.

Besides income, the demand for health care is affected by socio-economic factors. The important factors are education, environment, cultural heritage, race and religion. These factors are closely related to a very important demand influence, information. The choice of a physician is based almost always on previous performance in dissimilar situations for the patient or his acquaintances, and involves basically a decision to place himself entirely in his hands. Choice of other health care services are generally restricted to the recommendations of the physician, supported by a confidence in the completeness of his knowledge and the purity of his motives. Therefore, it can be seen that the demand for health care is not identical to the demand for an ordinary consumer good primarily because the costliness of information and the cost of misinformation necessitate the delegation of selection decisions to another party. Within this constrained framework, health care demand has the characteristics of the demand for ordinary economic goods, with limitations consistent with its intrinsic characteristics.

Supply Decision Processes

A study such as this cannot deal with all aspects of the economics of the supply of health care. It is concerned only with aspects which directly affect the health care an individual receives after entering the system. For the purposes of this discussion these factors are divided into three parts: first, the role of the physician's behavior in the treatment process; second, the decision making process within hospitals and how these affect the patient; and third, the behavior of the health care supply sector as a system.

Physician Behavior

The factors inducing individuals to become physicians and influencing their location decisions are of vital importance to a physician-deficient rural area, but are beyond the scope of this study.

A more pertinent question is, what factors does a physician consider in determining the health care facilities the patient will utilize in the treatment prescribed. This involves two basic choices, type of facility and location of facility.

The physician's selection of the type of health care facility used is restricted initially by what is available. This constraint may be very restrictive when a remote, sparsely populated area is considered, since two traits characteristic of most health resources are high cost and indivisibility. The physician's knowledge and experience represent a second limitation to the selection process. In rapidly changing environment of modern science, medical knowledge and technology advance at a rapid rate. The diffusion of this knowledge to the practicing physician is more gradual, restrained not by a lack of interest in keeping abreast of his profession, but by a lack of time remaining after handling his practice. The veteran practitioner is not the only one subject to this knowledge constraint. The vast amount of information available imposes a specialist system upon medical schools and their students, with the general practitioner knowing how to handle common ailments and to whom to refer the patient for unusual ones.

Within the constraints the physician selects a treatment regimen that he deems most appropriate. The degree of substitutability between resources varies greatly, depending largely upon the perception by the physician of the substitution possibilities. Many health planners foresee more substitution between inpatient and outpatient care as traditional attitudes of physicians and patients evolve, spurred by relative cost increases of inpatient care. The number of these decisions remanded to the patient depends upon the degree of indifference between the choices in the physician's mind.

A similar situation arises concerning location selection. While the alternatives in a rural area are decidedly fewer, instances do arise where a choice between equivalent hospitals must be made, often where one is more convenient to the patient, and another more convenient to the physician. The second is almost always chosen.

Lubin, Reed, et al. (1966) examine this question in Santa Clara County, California. They study physician's admitting practices and find that physicians whose specialty necessitates high usage or hospitals tend to locate their office closer to the hospital(s) they use than physicians with less hospital intensive practices. In addition, they find that a number of physicians utilize only one hospital, implying the patient's voice in hospital selection is negligible. Of physicians admitting patients to more than one hospital, the closer hospital generally receives more of the admissions. Overall, the study discovers that the physician's own travel time is an important criterion in his selection of the hospital his patients are admitted to.

Such behavior is consistent with the view of the physician as a profit maximizing entrepreneur, producing health care, with his own time a valuable input. If the physician envisions the patient's primary concern as the treatment necessary to cure his particular ailment, allowing the physician discretion to decide what is appropriate, then the physician has the latitude to satisfy this concern in the manner most convenient for himself. Considering the high opportunity cost on a physician's time, if the patient had to pay the full cost to a physician of utilizing a hospital more convenient to the patient and less to the physician, the patient would possibly find his own inconvenience the less costly.

Hospital Decision Making

In rural areas, the population served by a hospital often generates insufficient revenue to make the hospital self-sustaining, therefore, requiring some form of subsidy. In this situation inefficiency may mean the difference between continued service and suspension of operations. Such an environment makes the economics of hospital behavior very important, therefore, several theories will be examined, and an overview presented.

Reder (1965) discusses some of the obstacles to hospital efficiency associated with the non-profit nature of its organization. Among the problems are (1) many factors other than "medical necessity" influence the utilization of hospitals, (2) the use of third party payers reduces the financial penalty of overuse of facilities, and (3) the restriction on choice imposed by limitation to a hospital where the patient's doctor is affiliated reduces the risk of elimination for high cost producers. Much inefficiency is subsidized by spreading costs to all health insurance subscribers, without regard to the efficiency of the facility they patronize. Physicians encourage fully equipped hospitals, leading to duplication, and the administrator, being salaried, prefers size, completeness and modernness to profitability.

Lee (1971) uses the hospital administrator's utility function to explain the behavior of non-profit hospitals. This utility function has the status of the hospital as its only component related to the hospital. The decision maker desires a certain status for the hospital, and the hospital has an actual status, which is usually lower. While high status may be desirable for the status it accrues to its administration, high status is also important in attracting physicians to the hospital staff, and is related directly to the production inputs used. The inputs desired are dependent upon the inputs used by other hospitals in the same and higher status groups. Since the demand for hospital care is relatively price inelastic, the administrators can raise prices somewhat to accommodate their desire for increased status. The result is the use of more inputs in the production of health services than a profit-maximizing firm would employ, resulting in unwarranted duplication of equipment, personnel, and facilities.

Lee (1972) views hospital production decisions as a conspicuous production process, in which input usage is affected not only by necessity, but also by behavior of other hospitals. The relevant other hospitals are those having an equivalent or higher status, as viewed by the hospital administrators. This practice leads toward underutilization of inputs and the application of production techniques inappropriate for the type of care being provided.

Some alternative theories of non-profit hospital behavior are examined by Davis (1972) and contrasted to profit maximization. Quantity-quality maximization, utility maximization, and cash flow maximization are alternatives. Aggregate time series data comparing non-profit and profit oriented hospitals are examined to see if these are supported by the evidence. While the results are inconclusive, the data suggests: (1) the use of a breakeven constraint is inaccurate since non-profit hospitals consistently earn profits; (2) cash flow maximization is the best supported of the theories; and (3) non-profit hospitals are more inclined to obtain specialized facilities than their profit-oriented counterparts.

Joseph (1974) derives a model of hospital behavior based on group utility maximization by the decision makers. He finds that marginal cost must exceed marginal revenue, and that increasing insurance coverage can result in positive profit rates. He argues for inclusion of quality in the utility function despite lack of empirical verification, and for inclusion of the expected patients turned away, based on empirical evidence.

The behavior of hospitals and the rationale underlying this behavior is examined by Bilheimer (1974) using hospitals in Arkansas as the study group. Bilheimer begins with observed behavior and attempts to find an underlying consistency in it, rather than beginning with an abstract model and generalizing from it to the individual hospital. This approach does not have the simplicity of neoclassical economics so attractive to economists, but has added realism endearing it to decision makers. Concentrating upon the perspective of the administrator, environmental constraints imposed by others concerned with the hospital are identified and discussed. In this light, the environment in which the hospital operates is examined, and the decision process under different organizational forms is presented. The relationship between goals, objectives, and policy actions is examined and strategies and decision criteria are evaluated in conjunction with these and the environmental factors. By concentrating on observed behavior, the decision process is given a different perspective than available in the profit or utility maximizing models of Lee (1971, 1972), Joseph (1974) and others.

It is difficult to arrive at a consensus when explaining non-profit hospital behavior. However several conclusions may be drawn. Inefficiency in the form of too many services is a potential if not ubiquitous problem. Administrators are subject to considerable pressure from the hospital staff, the board of trustees, and large donors and/or funding agencies and status of the hospital seems to be important.

Health Care Supply from a Systems Viewpoint

The susceptibility of hospitals to external influences in major service and capital decisions and the role of status in the decision process suggests that treating hospitals and the remainder of the supply sector as a system is advisable to internalize some of these interactions.

A system analysis approach is used by Smallwood, Sondik and Offensend (1971) to conceptualize the flows within a health care system. The stochastic incidence of various diseases in the region are translated into a patient behavior model. The patient's state of health is then examined by the physician and based on his findings the physician places the patient into a category, or care region. Each care region has a corresponding care regimen, or treatment package. This treatment package includes demands for facilities and personnel in the region. A regional health program affects the system either at the disease incidence stage, through preventative programs or at the patient behavior stage when service programs alter the regional health care system, thereby altering the patient's response to a given state of health. The conceptual model, if accurately specified, would allow evaluation of many policies, including alternative expenditures in quite diverse areas.

The framework of Smallwood, Sondik, and Offensend (1971) is broader than merely health care supply. Within this system exists a smaller system containing the interactions described by Smallwood, Sondik, and Offensend and also those relationships of Bilheimer (1974) and Lee (1971, 1972). These studies emphasize the need for joint consideration of an area's hospitals and joint consideration of hospitals and physicians. The findings of Lee (1971, 1972) and Bilheimer (1974) suggest that a regional health program can affect both the definition of Smallwood, et al.'s care regions and the components of each care region's corresponding care regimen. Thus the system presented underemphasizes the potential impact of public actions on the actions of the supply sector.

Spatial Considerations in Health Economics

The dispersion of the population and the cost of bringing suppliers and demanders together affects the economics of health care as it does most products. Since travel costs time and money, separation of health demanders from a source of supply increases the cost of obtaining health care as the distance increases. Additionally, health services, particularly emergency health services, have an urgency which makes separation more serious than mere inconvenience. It is desirable for each individual to have health care easily accessible.

Having comprehensive health services available in every hamlet in Oklahoma would, of course, be prohibitively expensive. Unlike gasoline stations, hospitals come in units which require a substantial population to utilize them fully. The same is true for doctors, dentists, ambulances, and most medical equipment. When faced with this situation, most communities decide some lesser level of service accessibility is satisfactory. The choice rural residents face is between high cost for health services and not having certain services available locally.

Even when services are available, accessibility is a problem. This is true in both urban and rural areas because of travel time from the residence to the service facility. In urban areas, this is due to congestion, poorly located facilities, and immobility of the population. In rural areas, the lack of accessibility is due to distance and poor roads. Response to spatial considerations occurs in both the supply and demand sector. In the demand sector, residents must determine what services they are willing to support on the local level and how far they are willing to travel for each level of service.

Kane (1969) surveys a sample of residents in a rural Kentucky region concerning their attitudes and needs for health care. These rural residents feel that a local medical facility should provide (1) emergency care and (2) personalized medical care for routine problems. The residents recognize that travel is required to obtain more sophisticated services and are prepared to travel for them. Their travel patterns to obtain health care correspond to their travel for other reasons, e.g., commercial activity or recreation.

Since most local hospitals in rural Oklahoma are administered by local government, either municipal or county, and since these facilities often require some form of subsidy, citizens have a voice in determining how much health care they wish to support on the local level in a more direct manner than through normal market response.

Spatial perspectives affect supplier's actions as well. Long (1964) discusses ways of making better use of hospital facilities. His suggestions are: (1) use regional coordination to handle overflow during peak periods; (2) have within a hospital a few beds which can be transferred from one section to another; and (3) introduce policies to encourage patients with flexibility to use the hospital at other than peak periods. Using data from 14 Pittsburgh hospitals to discover how the additional costs associated with these measures compare to the associated savings in capital and operating expenses, Long finds with selective adoption of these policies savings may be significant.

Further discussion of the economic effects of the spatial distribution of population would only retrace an often-traveled path in regional economics. Rather, it seems appropriate to examine an overview of what has been done and move on. Such an overview is provided by Shannon, Bashsur and Metzner (1969). They study the role of distance in the utilization and accessibility of health care concentrating on the underlying assumptions of various approaches and the error introduced by such assumptions. In their view, the one glaring deficiency in the literature is the tendency to concentrate on distance and direction at the expense of incorporating differences in demand for health services associated with demographic and socio-economic characteristics.

Empirical Studies of Demand for Health Services

Estimation of the demand for health services must underlie any study of facility utilization. Since direct survey methods are very time consuming and expensive, an indirect method of estimation is generally used. Each method has its advantages and disadvantages, and comparison of their findings serves as a check of the method the researcher chooses. Each study is interested in different questions, the sum of which provide a composite picture of demand for health care.

"Economists have assumed that prices play an important role in the use of medical services, while medical care professionals have maintained that they do not influence medical decisions" (Davis and Russell, 1972, p. 109). With the desire to determine the role of prices in medical services demand, Davis and Russell estimate demand equations for outpatient visits and inpatient visits, using per capita admissions and mean stay as measures of inpatient visits. As independent variables, the prices of the goods, the prices of substitutes, and other economically based determinants of demand are used. The regressions show medical services to be ordinary economic goods, with substantial own and cross price elasticities. Davis and Russell also find that physicians substitute other care for inpatient care as occupancy rates rise. The existence of substantial cross elasticities suggests the considerable flexibility in policy decisions depending upon relative prices, thereby supporting the economist's assumption that health care is an ordinary economic good.

With usage data, aggregated on a county basis, Wennberg and Gittelsohn (1973) examine differences in utilization of health care facilities between health services areas in Vermont. They find significant differences in usage of facilities, number of facilities and personnel available and expenditures for health purposes between apparently similar populations. In particular, they discover variations in facility usage and treatment prescribed tend to reflect differences in the individual physician's practices or the practices of groups of physicians. Depending upon the difficulty of the procedures, the rate of general practitioners per capita tends to be associated with higher surgery rates for less complex procedures and lower rates for more complex. This disagrees with Davis and Russell (1972), as Wennberg and Gittelsohn consider physician's preferences to be largely responsible for differences in usage. It is impossible to determine which is correct since the studies are so different in their perspective, but it is evident that the role of the physician is substantial, and price differences, while a factor in some decisions, are decidedly secondary.

Holahan (1975), through the use and outlays in medicaid programs across states, studies (1) the effect of physician availability on usage, (2) the differences in usage between sociological groups, and (3) the effect the state's attitude toward the program has upon its usage. He finds that physicial availability strongly affects medicaid expenditures per user, supporting the theory that physicians can affect the level of demand of their services. Additionally, he finds that urban dwellers and whites use more services than rural dwellers and non-whites, respectively, and that states which support their medicaid programs actively have higher utilization rates than those which support them less. It is not stated how effective physicians can be in applying Say's Law to their services, but if these conclusions are correct, then communities which apparently could not support a physician, might do so with the higher than expected utilization induced by physician action.

Newell (1964) examines differences found in hospital usage rates in various studies. Distinguishing between current use of hospitals, which is measurable, and the demand for hospitals, which is not, he summarizes the techniques and findings of some British usage surveys, both population centered, and hospital centered. As does Feldstein (1967), Newell identifies the physician as a major determinant of the differences, due both to the tendency to prescribe remedies in light of available facilities, and to the ability to recognize a patient's ailment for what it is. Socio-economic factors are also deemed to be important sources of variation, although how is inconclusive. Newell emphasizes that demand for hospitals can be reduced by substitution of other types of care, e.g., outpatient and nursing, and any changes in hospital capacity should consider both economic factors and the primary goal of preserving the health of the people of the community.

May, Doeksen and Green (1977) estimate usage rates for hospital patient days, physician visits, ambulance calls, and emergency room visits. Using different sources for the different services, utilization rates based on observed usage are presented for cohorts divided by sex and age.

Most studies use a method similar to that of May, Doeksen and Green (1977) to determine the expected utilization of service facilities. However, the findings of Davis and Russell (1972), Wennberg and Gittelsohn (1973), Holohan (1975) and Newell (1964) suggest that health planners can proceed further from these initial estimates by making adjustments for actions of the physician in an area, or variations in relative costs of services.

Davis and Russell (1972) and Newell (1964) both allude to a degree of substitutability between alternative treatments for illness depending on circumstances. Many health planners overlook these opportunities, retaining a traditional view of the resources required to treat a problem. Since different costs are associated with different resources, communities may benefit by making a substitution. The economics of such substitution is the subject of the next section.

The Substitutability of Health Resources

The shortage of physicians in some areas of the U. S., particularly rural areas, has increased the interest in supplementing physician's services with physician extenders of various types. The potential for this substitution is the emphasis of part of this section. This substitution is not the only variety available. Some facility substitution is also possible. This may involve substituting outpatient care for inpatient care, substituting home convalescence for hospitalized convalescence, or substituting telephone consultation for physician office visits. Each of these substitutions is possible for only a portion of the cases now using a service, but encouragement of such substitution can decrease the required capacity of expensive facilities, such as hospitals, and replace them with cheaper facilities, such as clinics, and emergency rooms.

Davis and Russell (1972) find substitution between outpatient and inpatient care to be price responsive. Feldstein (1967, chapter 7) finds that when the number of available beds is small, substitution of outpatient care for inpatient care occurs and when considerable excess capacity exists, the reverse substitution occurs. Acton (1975) tests empirically the relative roles of hospital care, outpatient care, and physician's visits and finds that outpatient care and physician's visits are substitutes, each being complements to hospital care.

Holtman (1972) hypothesizes that substitution of time for dollar expenditures through substitution of cheaper, more time consuming treatments for more costly, quicker methods will take place depending upon the relative marginal costs of time and treatment variation. This suggests a high-salaried, busy executive will use telephone consultations rather than physician office visits whenever possible, and prefer inpatient treatment with its shorter convalescence to slower acting home treatment.

The incorporation of such substitution depends primarily upon the physician's awareness of the possibility for this substitution and his willingness to encourage it. Substitution of physician extenders for physicians involves the active recruitment of such an individual to the community after the physician, or physicians, decide it is worthwhile. Therefore, considerable planning is involved in such a decision, particularly by the employing group. A prerequisite for such planning is an understanding of the increase in the number of patients seen by the practice such an individual could allow, compared to the salary he would receive.

Boaz (1972) estimates a production function for a family planning clinic and uses it to examine productivity of the various personnel types compared to their salaries. In most instances, 17 out of 19 clinics studied, the marginal cost per patient of physician's services is lower than for other personnel, both professionals and non-professionals, indicating too large a physician to other personnel ratio.

Golladay, Manser and Smith (1974) divide the physician's practice into services in which a physician extender can provide the care required and those for which a physician is required. This information, combined with the case mix probabilities, provides the information necessary to derive optimal staffing mixes in light of the availability of personnel only in discrete units. The inclusion of physician extenders in the system substantially lowers costs for certain scales of practices. The authors determine that physician extenders can handle about 40 percent of the cases ordinarily handled by the physicians. Their resource requirements for treating various problems are based on observation of actual practices.

Smith, Miller and Golladay (1972) divide primary physician visits into a variety of services and the supply of each service into various tasks. By observation of actual practices, some of these tasks are determined to be delegatable to non-physician personnel. They find a registered nurse may be efficiently employed in a practice serving more than 138 patients per week and a physician's assistant may be efficiently employed if the practice exceeds 150 visits per week.

It is evident from the preceding discussion that analysis of substitution of resources in health care is restricted to either a theoretical level or such a general applied level that its usefulness to decision makers is minimal at present. Of more immediate relevance are the studies of operating costs of various types of health facilities, either in the form of budgeting studies or production and cost function estimation.

Costs of Health Facilities

Studies of the costs of supplying health care fall into two types. The first utilizes microeconomic methods and estimates cost functions or production functions translatable into cost functions. The second uses an economic engineering approach and prepares budgets for constructing and operating a facility of a specific size and type. Studies of each type have been conducted for hospitals and physician practices.

The economics of hospital cost is a common topic in the health literature, primarily because considerable difficulty has been encountered in obtaining results consistent with microeconomic theory. Perhaps the most satisfactory results from a theoretical standpoint are in Carr and Feldstein (1967). Using total cost as the dependent variable and patient days as the measure of size, they investigate the existence of size economies in hospitals, finding the average cost curve to have the u-shape traditionally hypothesized. To differentiate between quality differences, the number of ancillary services offered is used as an independent variable. Additional variables to remove the effect of nursing schools, medical schools, and intern programs are included. A second group of regressions, in which the hospitals are divided into several subsets according to the number of services offered, is run in order to remove the effects of multicollinearity between patient days and the number of services and finds similar results.

Evans and Walker (1972) find no strong evidence of the existence of long-run economies or diseconomies of scale in the hospitals in their study of British Columbia hospitals. Information theory is used to develop two alternative measures of case load complexity; the first strictly a measure of case-load complexity, and the second a measure of case-load complexity after the effects of differences in size are accounted for. Similarly, three measures of specialization are developed. Inclusion of some measure of patient mix and some measure of age-sex patient characteristics is found to be important in explaining cost differences between hospitals.

Lee and Wallace (1973) decide that the multi-product nature of the hospital makes analysis of output as a function of various common inputs unsatisfactory. They assert an effective method is to divide up the production analysis into individual products, in the case of hospitals, disease types. These then can be analyzed according to their specific inputs and the general inputs. Such data is not available but estimating cost as a function of the proportions of the cases with each disease type provides Lee and Wallace meaningful results, particularly when the breakdowns are quite specific.

The relation of case-mix proportions to hospital costs is also examined by Feldstein (1965). Using both aggregated cost figures and costs separated by type as his dependent variables, Feldstein finds that on a cost per case basis the case-mix differences explain a significant amount of the variation in all instances. When the cost per patient week is used as the dependent variable, the method Lee and Wallace use, important explanatory power is exhibited, but the observed significance level is considerably poorer.

The research concerning economies of scale in hospitals is reviewed by Hefty (1969) and insights into the methods are offered. Noting that all studies have been cross-sectional, and acknowledging the difficulty in measuring the product of a hospital, he compares and contrasts several studies. While all studies do not discover them, Hefty concludes that economies of scale do exist for hospitals, with the least cost size between two and three hundred beds. He also concludes that (1) estimating average cost rather than total cost is more correct, (2) a method of estimation including the proportion of patients utilizing a particular service seems attractive, and (3) inclusion of occupancy rate as an independent variable is inappropriate.

Lave (1966) analyzes the attempts to study hospital cost, categorizes them into a framework by method, and evaluates their success in meeting their goals. Two major shortcomings are apparent in all methods, the output of a hospital is difficult to measure and the type of data available is inadequate for these types of studies. She feels that the future success in measuring cost differences between hospitals will reflect the degree to which these deficiencies are overcome.

This concern with proper specification and estimation methods arises because the obvious methods yield monotonically increasing average cost curves. Just as difficulties arise in the estimation of cost and production functions for hospitals, the estimation of corresponding functions for physicians yields varied and perhaps conflicting results.

Radtke (1974) uses a three equation econometric model to estimate the production of health, the availability of physicians, and the income of an area. To measure health status he uses dollar losses due to early deaths to create a health index. The marginal physical product of a physician in the Pacific Northwest is estimated to be $35,511 for 1970. The average annual gross earning of physicians in this area in 1970 is $67,396. Hence for the region as a whole no shortage of physicians is present. Yet for many of the areas the benefit from an additional physician exceeds the cost of recruiting one, assuming income is the incentive required to attract physicians. When a comparison of the costs and benefits of using additional hospital beds as lures for physicians is made, Radtke finds that costs exceed the benefits for most rural regions and other methods of attracting physicians are more efficient. In particular salary subsidization, payment for part of the physician's training, and provision of a rent free clinic building, are all more efficient alternatives.

Theoretically, group practices should decrease average cost substantially since few diseconomies can be imagined from combination of individual practices while economies should exist from elimination of duplication in such areas as bookkeeping, reception, and lab activity.

Newhouse (1973) develops a theoretical model explaining variations in costs of outpatient medical practices as the group size varies. The basis of his model is the incentives the physician faces to reduce costs and work harder, with various organizations of group practices. The least incentive is provided by a clinic in which physicians are salaried. Here, all incentives are psychic, with pecuniary benefits unavailable for additional effort. Similarly revenue sharing decreases the marginal reward to the physician. The greatest incentive exists in the single physician practice where all marginal profit from additional labor or cost savings goes to the individual. Newhouse finds that for each subset of costs per visit a dummy for a cost-sharing system is positive, although no discernable difference appears in hours worked per week. Newhouse finds all reasons commonly given in support of group practice to be empirically unsupportable. Any potential economies of scale in group practices are apparently outweighed by lower productivity.

Scheffler (1975), in a note concerning Newhouse (1973), estimates the number of personnel per physician, both medical and non-medical, to study the economics of group practice. A distinction is made between a physician manager and a non-physician manager. The size of practice does not affect personnel per physician ratios significantly for either personnel type, but the type of manager and the homogeneity of the practice does in both cases. Physician managers use more medical personnel and fewer non-medical personnel than do their non-physician counterparts and homogeneous specialty practices use more medical personnel and fewer non-medical personnel than do mixed specialty practices. He, like Newhouse, finds no scale economies in larger practices.

Evans, Parish and Sully (1973) use British Columbia physicians to investigate the effect on output per physician of group practices and to investigate the ability of physicians to generate demand. No scale economies are found for large groups, perhaps because members of large groups work fewer hours. This hypothesis is consistent with Newhouse (1973). Two to four physician practices do, however, exhibit substantial advantages over both larger and solo practices. The regressions also show that total workload has an elasticity of 0.85 with respect to the introduction of new physicians, suggesting either a substantial ability for physicians to generate demand or a universal backlog of unmet need, which existing physicians ration between themselves. A third possibility, that additional physicians lower the total cost to the patient, is also offered. These alternatives are rejected in favor of the demand generation explanation.

Cordes (1973) studies 17 practices, comprised of 41 doctors in rural Washington, to investigate economies in size of practices. Two measures of physician productivity, office visits per physician hour in the office and per physician hour in direct patient care, are used. Except for two-man practices, productivity increases as the number of doctors practicing together increases using either measure. This increased productivity is due partly to reduced administrative and clerical duties, a large item for single physician practices.

Intermingled with the economies of group practice apparently there are other factors, which conceal the savings obtained, in particular the tendency for physicians in larger practices to work fewer hours. Since health care costs are so affected by factors peculiar to the individuals in influential positions, health planning is made more complex. Perhaps the only reasonable way of handling cost planning is an economic engineering approach, where basic budgets are derived and are adjusted according to the peculiarities of each situation. Radtke and Nordblom (1975b) is an example of such a budget for a small rural hospital.

Radtke and Nordblom (1975a) do a budgeting study of a small physician practice in a rural area, specifically Nevada. In it they estimate that the breakeven number of patients in a single physician clinic is 6,783 patient visits per year, and 12,663 patient visits per year for the two physician clinic. Assuming 90 percent bill collection, 7,537 patient visits per year are required to support the single physician clinic. Assuming further that 75 percent of the population in the area utilize local physicians, a population of approximately 2,000 persons is required to support a physician using a rate of five visits per person per year.

Doeksen, Frye and Green (1975) outline in a similar manner how a community or county might evaluate their ability to purchase, staff and support an ambulance service.

Using as a basis a method similar to those presented in the preceding three articles, Radtke (1975) evaluates the health situation in a rural Nevada county. Alternatives considered are (1) subsidization of the local hospital of its operating deficits, (2) guarantying the incomes of all the physicians in the county, thus subsidize them in case of a shortfall in revenues, (3) setting up a county clinic, (4) closing the acute section of the hospital, and (5) requiring that the hospital reduce its costs substantially and that the hospital physician practice independently. Each of these alternatives are examined using fundamental budgeting and expected demand methods.

These studies provide guidelines for estimating costs of health facilities and point out pitfalls to avoid. When estimating cost functions, realized economies of size are generally so small that they do not appear significantly in results. Budgeting is an alternative appraoch but it too has its deficiencies. The major problem in budgeting studies is providing a representative example.

Facility Location and Utilization

An entire subgroup of the health economics literature deals with the location and optimal size of health facilities. The problem is effectively divided into two groups, optimal location and optimal size.

Location

A very simple approach to the location problem is taken by Lubin, Drosness and Wylie (1965). The highway system in the Santa Clara, California areas is computerized in terms of time required to travel from one point to another. Then the most efficient routes, as measured by travel time, between all point combinations are calculated by some routing procedure. In an area which requires a new facility, health or otherwise, the best location is defined as that in which the largest number of persons are within a certain number of minutes travel time from that point.

Eddleman (1972), defining total cost as the sum of travel costs and health service production costs, finds the optimal hospital locations using total access cost minimization. Considering both alternative locations and different numbers of facilities, he finds optimum locations for a nine county area in Florida.

Murray (1972) carries the same methodology further, enlarging the study area and improving the underlying data. Deriving a production cost function and extrapolating trends in hospital usage, he determines the least cost hospital location and numbers for 17 Florida counties and finds the least cost plan to be two locations compared to 14 present sites. A saving of six million dollars annually could be achieved by such a plan. Applying a cost equity criteria, a five site plan proves optimal with an additional 1.5 million cost over the two site plan. The implications are that considerable potential economies exist by decreasing the number of facilities and increasing the size of some smaller facilities to nearer the least cost size, 406 beds. If these savings are channeled into a transportation system, the rural areas need not experience substantially poorer accessibility.

Hardy, Marshall, and Faris (1973) derive optimum locations for Health Outreach Clinics in Virginia. Using a locational algorithm, they minimize total patient miles traveled subject to constraints of capacity, facility number, and satisfaction of demand for each area. The locations are derived under varying assumptions for distance traveled, number of clinics, and referral rates to hospitals, and are found to be very sensitive to changes in these variables. The final question of how many clinics are appropriate is left unanswered, with the criterion being comparison of the additional cost of establishing another clinic with the cost of the population that clinic would serve having inadequate access.

Abernathy and Hershey (1972) conceptualize the spatial location problem as one of conflicting goals, each yielding a different solution. They select four objectives deemed reasonable for location selection of health centers, and solve the location problem in accordance with each. Their objectives are: (1) maximize utilization; (2) minimize distance per capita; (3) minimize distance per visit; and (4) minimize percent degradation in utilization. The second and third objectives are different since visits are a function of distance, socio-economic and health status factors. The fourth objective attempts to minimize the negative effects of distance upon utilization. The choice of weighting the objectives and hence selection from alternative solutions is left to the decision makers, but the method effectively reduces their choices and allows them to objectively analyze the implications of their choice with regard to at least four criteria.

The locational efficiency of urban hospitals is studied by Schneider (1967). The basic efficiency desired is a balance of the various attractive forces on the hospital's location, using the concept of a community indifference curve to determine the weights appropriate for these various elements. While using only a simplified version of the system for his empirical example, Schneider's theoretical system contains seven groups which have a preference regarding the hospital location. For each of these group's per trip travel cost two sets of weights are appropriate. The first is society's relative valuation of the importance of each group's time and expense, and the second is the frequency of each group's trips to the hospital. These weighted amounts have a spatial orientation, and therefore can be viewed as vectors acting upon the present location from various directions. They cancel each other to a large extent, but unless the present location is the most efficient, a residual vector will remain having both direction and length, indicating the most efficient location. By certain simplifying assumptions concerning the weights, the problem may be reduced to a reasonable size and policy implication can be examined. No attempt is made to include economizing forces other than travel.

Toregas, Swain, ReVelle and Bergman (1971) study the problem of emergency facility location as a problem of minimizing the number of facilities, subject to the constraint that no consumer is further than some fixed distance away. Linear programming is used to choose the sites, treating all facilities as having equal cost regardless of service area. Integer constraints are introduced to restrict supply locations to whole facilities, and no acknowledgement is made of the existence of any present facilities beyond the restriction that they not be located at a point without any resident demanders, i.e., all facilities are restricted to towns.

Studying a similar problem but offering a larger variety of decision criteria, Oehrtman and Doeksen (1976) use linear programming to determine optimal emergency facility location for rural areas. With three alternative objectives: (1) minimum response time, (2) minimum total mileage, and (3) maximum protection, they determine the optimum location for each facility according to each objective function and evaluate the other objective functions to measure the efficiency loss using that particular criterion. While the example is for fire protection, the procedure is equally applicable for ambulance service.

Utilization

An important distinction in the applied research of hospital location is the difference between the question of where should the hospitals be if the decision regarding their location were made today using economic criteria and which hospitals are the wrong size according to some economic criterion, given that their location has already been established. The first of these questions was addressed above by Eddleman (1972) and Murray (1972). Edwards and Doherty (1971) address the second. The effect of regional cooperation on the capacity necessary to meet unusually high levels of demand for hospital beds is considered using queuing theory. The properties of the Poisson distribution, with which patient arrivals are assumed to be distributed, make the capacity necessary for hospitals viewing themselves as independent units greater than if they acknowledge each other's presence and view an empty bed in another hospital as an available bed for one of their own patients should they be full. In the study area of Edwards and Doherty, it is apparent that some hospitals take such a view, since they accept a probability of overcrowding as frequently as every two weeks.

Ault and Johnson (1973) develop a model to approximate geographic service areas of hospitals. Dealing with a metropolitan situation, Ault and Johnson list as factors affecting hospital choice: (1) time required to reach a hospital, (2) the size of the hospital complex, and (3) the number of services provided. These are combined in a probabilistic model which estimates probabilities of traveling to different hospitals on the basis of these factors. This model and variations on it are powerful for their cost and the data requirements are slight.

Long and Feldstein (1967) study the peak load problem as a system rather than a single unit problem. Theoretically, the optimum number of beds should be determined by minimizing total costs, which are the sum of the hospital cost, travel costs, and inconvenience costs or the costs associated with changing plans because the preferred facility is full. These costs are not all measureable so alternative methods are used and compared as a substitute measure. The alternatives considered are (1) a queuing theory approach where the number of beds is determined by selection of an acceptable rate of special handling, i.e., inconvenience to patients, per 1,000 cases, and (2) a cost minimization approach where an arbitrary inconvenience cost (the authors use alternatively $500 and $250) is used and the optimum size is determined by equating marginal costs of inconvenience with the marginal cost of extra capacity. By solving for various penalty costs and travel costs, choices for facility size and the accompanying implications are presented so regional planners can choose objectively. The study indicates that the consolidation suggested by scales economies in hospital costs is less imperative when all costs are included, particularly if inter-unit coordination is improved.

The cost of inconvenience also appears in Joseph and Folland (1972). Rather than arbitrarily assign a value to it, they estimate the value administrators place on it. Assuming patient arrivals are Poisson distributed, it is possible to calculate the probability that the demand on any day will exceed capacity if the average daily census and the capacity are known. The authors estimate the marginal probability for turnaway, as expressed by Iowa hospital administrators in their capacity decision, to be 0.64/1,000, i.e., a marginal bed is provided so that 0.64 patients will not be turned away each 1,000 days. The cost of having this bed idle 99.936 percent of the time is found to be $49,200, which means the administrators demonstrated a willingness to incur a cost of $49,200 to avoid turning away a patient.

In addition to the probabilistic methods discussed, the utilization problem is also approached using other methods. Duncan (1975), and Duncan and Heady (1976), use linear programming with cost minimization as the optimization criterion to study hospital usage in Northcentral Iowa. Their model allows them to determine (1) what effect manpower constraints have on utilization, (2) what future utilization patterns will be, (3) what effect changes in services offered by one hospital have on utilization, (4) how these changes affect the cost to the patient, and (5) what changes in present facilities result in cost savings. Dividing hospital care into five service categories, a matching of supply and demand locations through transportation activities is used to determine the patient load at each hospital for the service categories.

Morrill and Earickson (1968) study the variation between hospitals and how this relates to their clientele's travel distance. Principal components are used to reduce a large number of descriptive variables (99) to a small number (9) of descriptive dimensions. These dimensions involve internal and external characteristics of the service areas. The hospitals, using these dimensions, are divided into seven groups for homogeneity within and heterogeneity between groups and the distance traveled to the hospital is studied for each group. The results provide empirical verification of expected behavior: (1) hospitals offering many services draw patients further than those offering few; (2) hospitals offering very special services exhibit less distance attrition than regular hospitals; and (3) isolated hospitals monopolize their surrounding area more than those in competitive clusters.

In a second study, Morrill and Earickson (1969) construct a model to simulate usage of physicians and hospitals. Breaking the population into relatively homogeneous groups, they use a combination of a probabilistic and deterministic process to distribute this population between its alternatives. In this manner supply locations which are over or under used based on their decision criteria are identified, and possible shifts in or additions to physician numbers and hospital capacity on a locational basis are evaluated.

As these studies indicate, many alternatives are available to study facility location and utilization problems. Comparison is difficult because the specific problems vary as does the availability of data. Gross (1972) provides an overview of the methods used for planning future hospital needs, examining the strengths, limitations, and potential of each. He notes that optimal size of facilities and optimal location have been the primary goals to date, while no effort has been made to determine if these are the goals of the delivery system, or what any accompanying goals might be. Additionally, these two goals have been approached individually but not jointly, hence the tradeoff between size related economies and location related economies is not explored. Also, many determinants of utilization are regularly excluded, often without acknowledging their omission. Gross suggests more emphasis on the behavioral aspects of health service utilization is required.

Summary

The important characteristics of demand for health care emphasized is the literature which are included in this study are: (1) differences due to age and sex of the user; (2) responsiveness to the price of the services; (3) recognition of the role of the physician in the choice process; and (4) inclusion of third party payment effects. Supply characteristics emphasized in the literature which are included in this study are: (1) recognition of the role of the physician in supply decisions; (2) behavioral adjustments related to the economics of non-profit hospitals; (3) exclusion of scale economies from cost estimation; (4) utilization information giving case-mix differences; and (5) interaction between services.

The spatial studies of facility utilization have one especially significant gap. They treat only one service at a time, despite the contention of health planners, empirically supported by Lubin, Reed, et al. (1966), that physician choice is the major determinant of hospital choice. Duncan and Heady (1976) consider jointly different hospital services but interaction between services is not considered. Interaction between jointly considered services is an important characteristic of this study.

As noted previously, Gross (1972) stresses the need for inclusion of the goals of the health delivery system in an analysis of it. This is done. A multiple goal approach is used, a technique not used previously for more than a single service. Perhaps the most important suggestion of Gross incorporated in this study is the inclusion of some of the behavioral aspects of health service utilization. Their inclusion is especially important to health planners, since this is a side of health service usage they work with daily.

CHAPTER III

THE MODEL

Introduction

The major purpose of this model is to simulate actual behavior in the health care system accurately enough to make it a useful aid in health care planning. More specifically, the spatial usage of health resources on a multi-county area is the system to be examined. A spatial equilibrium model is established using linear programming with several alternative objective functions considered. The two most important of these functions are minimizing total patients health expenditures, or cost, and minimizing total patient travel. These correspond to the legislative directives of the Oklahoma Health Systems Agency of cost, availability and accessibility, and are goals of health planners generally.

The method used for the model is mixed integer linear programming. Linear programming is chosen because it has the capability of handling a large problem for low cost yet include most of the features deemed necessary for inclusion of this model. Other methods such as quadratic programming, simulation, and several routing procedures could handle the same problem and include more features of the health care system, but only at considerable cost in programming time and money. The mixed integer option of linear programming is used when new investment is considered. This option allows the limitation of investment to integral units, rather than the continuous units required by ordinary linear programming. Before proceeding further, a note on linear programming is appropriate.

Linear Programming

Linear programming is a method of minimizing a linear objective function subject to linear constraints. Use of linear programming involves several assumptions, the most restrictive of which is linearity of all relevant constraints and the objective function. Additional assumptions are: (1) activities must be additive, i.e. there can be no interaction between activities in the form of complementarity. This assumption necessitates the exclusion of the cross product term in the equation

$$Z = ax + by + cxy;$$

(2) all functions must be continuous, therefore, all inputs and products must be infinitely divisible; (3) the problem must be of finite proportions; and (4) all resource requirements, objective function coefficients, and resource supplies must be known with certainty (Heady and Candler, 1958, pp. 17-18). Various methods are available to relax these assumptions, such as mixed integer programming which overcomes difficulties due to the divisibility assumption, but these methods are useful only when a small number of exceptions are encountered.

Overview

The model is divided into two major sectors, a supply sector and a demand sector, with interaction between the sectors determining how demand is satisfied. Within each sector certain interactions occur which determine the composition of supply and demand.

An overview of the relationships of the system is shown in Figure 2. In this hypothetical system there are two locations, A and B, and two services, a and b. Beginning with a known population, known facilities, and known personnel pools in A and B, a solution is reached whereby all the demand for health services a and b is satisfied either by existing facilities and personnel or through investment in additional facilities and hiring of more personnel.

The population information is used as input for the incidence model, which, through combination of the susceptibility of each subset of the population to various ailments with the size of these population subsets, derives the expected incidence of these ailments in cases per year for the population in question. These incidence numbers are inputs for the care regimen model yielding the annual expected demand for each health service type by residents of that location. These residents satisfy this demand by choosing between alternative sources of supply of each service, basing their decision on the criterion implied by the applicable objective function.

The supply of service in each location is determined by the stock of facilities and personnel in that location. Some facilities and personnel have flexibility in the types of service they offer while others do not. Should either the facilities or the personnel in a location prove inadequate, additional amounts are available in integral units. Whether they are obtained or not depends upon the value of the objective function with them versus its value with the additional travel required when insufficient supplies are available locally.

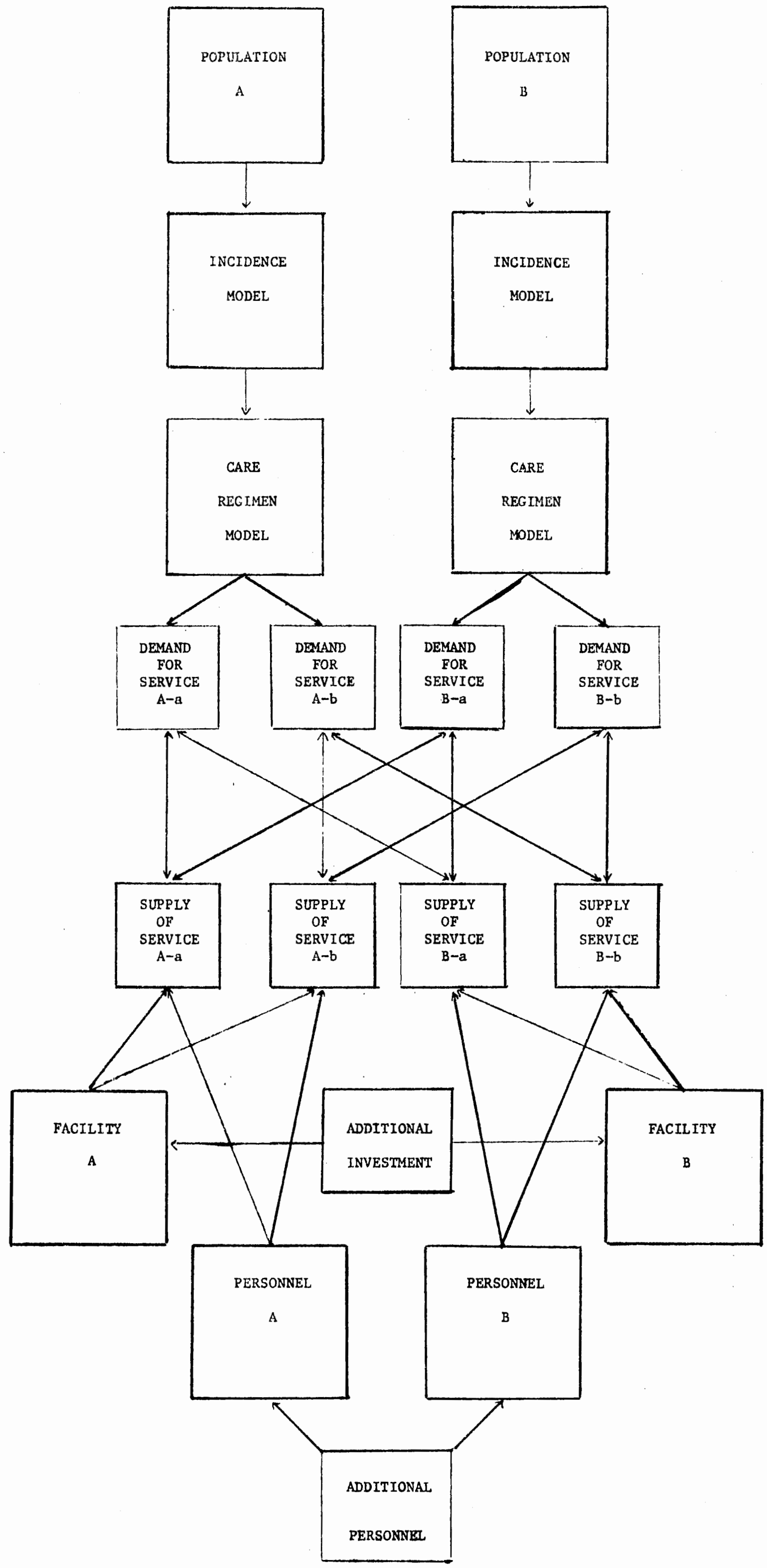


Figure 2. System Relationships for the Two Location, Two Service Model

Individual sectors of the model are discussed in depth in the following sections, beginning with the demand sector, followed by the supply sector and the interaction sector. Then the objective functions are presented with the rationale for each.

The Demand Sector

The demand sector requires two major decisions: how many locations and how many services should be included. These decisions are controlled by two factors, the availability and the accuracy of the data.

Population Sector

In this study, 27 demand locations are included. These are the 16 counties in the study area and the 11 communities with populations of greater than 2,500 residents. This delineation is based solely upon the available population data, these being all the units for which cohorts of the population consistent with the incidence model are available in the 1970 Census of the Population. A cohort approach is apparently necessary, since Solon (1966), and others, find that patients' demands for medical care are entwined thoroughly with their demographic characteristics.

The population cohorts used are: less than 15 years, 15-19 years, 20-29 years, 30-39 years, 40-44 years, 45-49 years, 50-59 years, 60-64 years, 65-69 years, 70-79 years and greater than 80 years of age, for both sexes, hence 22 cohorts in all.

Population Projections. Future population determines future demand and as such, its accurate estimation is fundamental to successful estimation of usage of proposed facilities. The population model utilizes a traditional population projections model as found in Hamilton, et al. (1969). The model is as follows for each demand location.

$$POP_t = \sum_{j=1}^{2} \sum_{i=1}^{11} G_{ijt}$$

where POP_t is the population in time t, and G_{ijt} is the population in time t in cohort i for sex j.

$$G_{i,j,t} = G_{i,j,t-1} + AG_{i-1,\ j,\ t-1} + M_{i,j,t-1} - AG_{i,j,t-1} - D_{i,j,t-1}$$

where $G_{i,j,0}$ is the initial population in cohort i of six j, $AG_{i,j,t}$ is the advancement from group i to group i + 1 between year t and year t + 1, $M_{i,j,t}$ is the net migration into group i between year t and year t + 1, and $D_{i,j,t}$ is the deaths by members of cohort i of six j in year t to t + 1.

$$AG_{0,j,t} = \sum_{i=1}^{11} B_i\ G_{i,2,t}$$

where $AG_{0,j,t}$ is the births of sex j in year t and B_i is the birth rate for women in cohort i.

$$D_{i,j,t} = D_{i,j,0}\ T_{i,j} G_{i,j,t}$$

where $D_{i,j,0}$ is the initial death rate for group i and $T_{i,j}$ is the trend in death rate for group i,j. Birth rates, death rates, and the trend for both are from the Statistical Abstract of the U. S. (U. S. Bureau of the Census, 1976). Oklahoma data consistent with the later uses of the model is not available so national data is used.

Migration is calculated as the mean of the average annual migration rates for two periods, 1960-1970 and 1970-1975. These periods are used because (1) they represent the two most recent non-overlapping periods for which migration estimates are available, and (2) because of the lack of a more continuous data series. For example, Alfalfa County had a 1.7 percent migration for the period April 1, 1970-July 1, 1975 or 0.32 percent per annum for this period. From April 1, 1960 to April 1, 1970 an 11.5 percent emigration occurred or 1.15 percent per annum. The mean of these two rates is an outmigration of 0.41 percent. Since only county migration figures are available, cities are assumed to have their county's rate. These migration rates are given in Table I. The relative mobility variables are all assumed to be 1.0. Since migration rates are the major source of error in population projections, the effect of error in migration estimates will be examined.

Incidence Model

Hospitalization rates for 18 classes of ailments for Oklahoma are taken from May, Doeksen, and Green (1977), who obtain them from Oklahoma Blue Cross-Blue Shield. These 18 categories are the classes used by Blue Cross-Blue Shield in their record keeping system and are those recommended by the National Center for Health Statistics (1967). When these rates are multiplied by the expected stay for these ailments for an age cohort, an expected utilization rate of hospital facilities for a person in that cohort for each illness category is obtained. The incidence rates are found in Table II, the expected stays in Table III, and the expected hospital utilization, in days per year, per 1,000 people in that cohort are found in Table IV.

As an example, suppose a county has 200 boys less than 15 years of age. They would then be expected to be hospitalized 200 x 3.0/1000 = 0.6 times per year for illnesses of the infective and parasitic

TABLE I

MIGRATION RATES FOR THE STUDY AREA

County	Rate of Migration (%)
Alfalfa	-0.41
Beaver	-1.33
Blaine	0.22
Cimarron	-1.38
Dewey	-0.86
Ellis	0.30
Garfield	-0.10
Grant	-0.68
Harper	-1.06
Kay	-0.81
Kingfisher	0.40
Major	0.42
Noble	-0.04
Texas	0.76
Woods	-1.16
Woodward	0.38

Source: Derived from Oklahoma Employment Security Commission (1972 and 1975).

TABLE II

INCIDENCE RATE FOR VARIOUS DISEASE CATEGORIES BY AGE AND SEX COHORT

Disease Categories	MEN <15	MEN 15-44	MEN 45-64	MEN 65+	WOMEN <15	WOMEN 15-44	WOMEN 45-64	WOMEN 65+
	(cases per 1000 population)							
Infective and Parasitic	3.000	3.800	3.400	6.800	2.400	7.100	5.000	21.100
Neoplasms	0.700	2.700	14.400	74.000	0.500	14.100	28.800	82.600
Endocrine, Nutritional, and Metabolic	0.500	1.700	4.200	12.300	0.700	4.400	8.000	23.000
Blood and Blood Forming Organs	0.600	0.400	0.800	2.000	0.300	0.700	1.100	4.500
Mental Disorders	0.400	4.200	5.500	15.100	0.200	7.200	7.600	15.400
Nervous System and Sense Organs	5.400	3.100	8.200	25.300	4.000	5.100	9.800	32.000
Circulatory System	0.400	5.900	40.600	154.800	0.300	7.900	28.900	138.300
Tonsillectomy	8.600	1.000	0.100	0.0	9.400	5.300	0.200	0.600
Respiratory System	10.400	13.300	26.500	86.300	7.500	19.200	27.400	90.900
Digestive System	4.300	9.500	24.900	58.200	2.300	15.300	26.900	85.100
Genitourinary System	2.500	8.700	18.300	58.900	3.800	45.600	38.700	67.200
Maternity Care	0.0	0.0	0.0	0.0	0.0	37.100	0.100	0.0
Skin and Subcutaneous Tissue	0.900	2.600	2.400	4.100	0.800	2.600	3.100	7.000
Musculoskeletal System and Connective Tissue	0.800	7.600	13.100	20.500	0.800	9.000	19.700	53.800
Congenital Anomolies	2.100	0.700	1.300	1.400	1.200	1.000	1.000	1.900
Certain Causes of Perinatal morbidity and mortality	1.900	0.0	0.0	0.0	18.000	0.0	0.0	0.0
Symptoms and Ill-Defined Conditions	2.900	5.400	11.600	55.500	2.400	10.800	14.500	76.200
Accidents, Poisoning and Violence	6.200	12.400	12.800	27.400	4.000	12.400	15.100	43.500

Source: May, Doeksen, and Green (1977)

TABLE III

AVERAGE LENGTH OF STUDY FOR VARIOUS DISEASE CATEGORIES BY AGE AND SEX COHORT

	MEN				WOMEN			
Disease Categories	<15	15-44	45-64	65+	<15	15-44	45-64	65+
Infective and Parasitic	3.700	4.400	5.500	4.000	3.900	4.500	5.100	5.500
Neoplasms	4.400	5.000	8.500	9.200	4.100	5.800	8.700	8.800
Endocrine, Nutritional, and Metabolic	4.100	5.200	6.900	7.200	7.300	5.100	7.400	8.400
Blood and Blood Forming Organs	3.900	4.700	6.400	5.700	3.100	4.000	4.600	3.700
Mental Disorders	15.600	10.000	9.100	10.800	12.900	11.100	11.100	10.000
Nervous System and Sense Organs	2.500	5.800	5.200	2.900	2.100	4.600	4.800	4.500
Circulatory System	5.000	6.100	8.700	6.800	4.700	7.400	8.500	9.000
Tonsillectomy	1.600	2.600	5.000	0.0	1.600	2.500	3.400	5.000
Respiratory System	3.600	4.100	6.000	7.500	3.700	4.400	6.700	7.900
Digestive System	3.400	5.600	6.800	7.600	4.000	7.100	8.200	8.500
Genitourinary System	2.600	3.500	5.400	6.200	2.800	4.800	5.700	7.100
Maternity Care	0.0	0.0	0.0	0.0	0.0	3.800	2.500	0.0
Skin and Subcutaneous Tissue	3.100	4.900	4.600	7.800	2.900	3.900	6.600	9.900
Musculoskeletal System and Connective Tissue	4.300	6.200	7.100	8.400	5.900	6.700	8.000	7.900
Congenital Anomolies	4.900	5.600	8.800	3.500	5.700	4.800	8.200	5.000
Certain Causes of Perinatal morbidity and mortality	9.100	0.0	0.0	0.0	8.300	0.0	0.0	0.0
Symptoms and Ill-Defined Conditions	3.200	4.100	5.400	2.800	3.600	5.200	6.000	4.100
Accidents, Poisoning and Violence	3.900	5.300	6.500	7.800	4.300	6.400	7.800	9.800

Source: May, Doeksen, and Green (1977)

TABLE IV

AVERAGE ANNUAL HOSPITAL USAGE FOR VARIOUS DISEASE CATEGORIES BY AGE AND SEX COHORT

Disease Categories	MEN				WOMEN			
	<15	15-44	45-64	65+	<15	15-44	45-64	65+
Infective and Parasitic	11.100	16.720	18.700	27.200	9.360	31.950	25.500	116.050
Neoplasms	5.080	13.500	122.400	680.800	2.050	81.780	250.560	726.880
Endocrine, Nutritional, and Metabolic	2.050	8.840	28.980	88.560	5.110	22.440	59.200	193.200
Blood and Blood Forming Organs	2.340	1.880	5.120	11.400	0.930	2.800	5.060	16.650
Mental Disorders	6.240	42.000	59.059	163.080	2.540	79.920	84.360	154.000
Nervous System and Sense Organs	13.500	17.980	42.640	73.370	8.400	23.460	47.040	144.000
Circulatory System	2.000	35.990	353.220	1362.240	1.419	58.460	245.650	1244.700
Tonsillectomy	13.760	2.600	0.500	0.0	15.040	13.250	0.680	3.070
Respiratory System	37.440	54.530	159.000	647.250	27.750	84.480	183.580	718.110
Digestive System	14.020	53.200	169.320	442.320	9.200	108.630	220.580	723.350
Genitourinary System	5.500	30.450	98.820	365.100	10.640	218.880	220.590	477.120
Maternity Care	0.0	0.0	0.0	0.0	0.0	140.980	0.250	0.0
Skin and Subcutaneous Tissue	2.790	12.740	11.040	31.960	2.320	10.140	20.460	69.300
Musculoskeletal System and Connective Tissue	5.440	47.120	93.010	172.200	4.720	60.300	157.600	425.020
Congenital Anomolies	1[illegible].290	5.920	11.440	4.900	6.840	4.600	8.200	9.500
Certain Causes of Perinatal morbidity and mortality	17.290	0.0	0.0	0.0	149.400	0.0	0.0	0.0
Symptoms and Ill-Defined Conditions	9.260	22.140	62.040	155.400	8.640	56.160	87.000	312.420
Accidents, Poisoning and Violence	24.160	65.720	63.200	213.720	17.200	79.360	117.780	426.300

Source: May, Doeksen, and Green (1977)

category. With an average stay of 3.7 days, they would average 2.22 days in the hospital per year for these reasons. These 2.22 patient days, added to the corresponding number of patient days for the other cohorts, would be the expected total number of patient days from that county for infective and parasitic reasons.

Use of these rates carries with it the following caveats. The rates are 1975 data. Over time, both incidence rate and lengths of stay may change. The rates are for people who are insured. There is no guarantee that their behavior is identical to the non-insured population. The sample is extremely large, 465,000 people, making the figures reliable for what they measure. Carryover would seem reasonable to regions having similar populations and to the uninsured population. Changes in usage over time would appear to be the greatest problem and in later sections will be addressed.

Insufficient data prevents direct relation of incidence of these diseases to utilization of other services. Additionally, utilization independent of hospitalization is not included using this approach. Therefore ambulance calls, emergency room visits, and ambulatory care or physician visits are direct population-based utilization rates rather than rates using the population-disease incidence-service linkage.

The ambulance usage data is from Doeksen, Frye, and Green (1975). Based upon observed usage for an eight county area in Northwestern Oklahoma, a subset of the area for this study, demand for emergency medical calls, excluding highway accidents and patient transfers, is related to the age of the population. These average usage rates are found in Table V. For example, if a county had 400 residents less than

TABLE V

UTILIZATION RATES FOR AMBULANCE SERVICE FOR OTHER MEDICAL CALLS

Age	Utilization Rate
(calls per 1,000 population)	
19 and under	3.23
20-29	10.66
30-39	11.29
40-49	8.81
50-59	21.15
60-69	37.81
70-79	137.87
80+	216.95

Source: Doeksen, Frye, and Green (1975).

20 years of age, they could expect 3.23 x 400/1000 = 1.29 calls per year from this group. Doeksen, Frye, and Green suggest using local records to estimate highway accident and transfer calls, since both are dependent upon local conditions rather than general population characteristics. These usage rates are for a rural area and must be applied gingerly to metropolitan areas. This study includes no cities larger than 50,000 and only two cities larger than 10,000, so their use overall is not unwarranted.

Transfer calls are included as part of the care regimen model and highway accidents calls are added into the other medical calls at the end of the care regimen model.

The accident calls are estimated by averaging the highway accidents for the counties for 1970-1972 and assuming 20 percent of these require an ambulance. In those counties containing a community considered independently, the accident calls are assumed to be proportional to other ambulance calls in their distribution between county and city. A listing of these highway accident ambulance calls is given in Table VI.

The 20 percent figure is slightly lower than the rate of highway accident ambulance calls for the area illustrated in Doeksen, Frye, and Green (1975), but a slightly lower rate seems justified in light of the 55 mile per hour speed limit.

Emergency room utilization rates come from May, Doeksen, and Green (1977). This rate is derived from the 1976 Oklahoma Hospital Utilization Report (Oklahoma Health Planning Commission, 1976) and is a rural rate, derived from only rural sub-state planning districts. A general rate of 221.4 visits per 1,000 residents per year is used with no age or sex cohort breakdown.

TABLE VI

HIGHWAY ACCIDENT AMBULANCE CALLS

Location	Number
Alfalfa County	27
Beaver County	14
Blaine County	32
Cimarron County	12
Dewey County	21
Ellis County	10
Garfield County	70
Grant County	16
Harper County	13
Kay County	50
Kingfisher County	31
Major County	18
Noble County	17
Texas County	43
Woods County	22
Woodward County	43
Watonga	13
Enid	255
Blackwell	40
Ponca City	110
Tonkawa	16
Kingfisher	17
Fairview	11
Perry	21
Guymon	35
Alva	30
Woodward	43

Physician utilization rates come from two sources. The first are unpublished data of the Oklahoma Health Systems Agency, based upon the Quality of Life in Oklahoma Study, 1976, conducted by the University of Oklahoma. These rates are incomplete with no information for people less than 18 years of age. For this younger group, national rates are used to generate a synthetic estimate. This is done by taking the percent of total visits by this group nationally and applying it to the Oklahoma rates. The 18-44 rate is used for the 15-17 age groups, for which no rate is available. The resulting utilization rates are given in Table VII.

Care Regimen Model

The care regimen model translates the demand for hospital days according to disease into demand for specific services. Ideally, this would mean demand for the different ancillary services, as well as the basic bed-day. Practically, this means delineating these bed days into days of primary hospital care, available at a small rural hospital, and more specialized care, available only at larger hospitals.

To be more specific, MacQueen and Eldridge (1972) define them as follows:

> Primary care services are generally considered to include basic acute care services of limited complexity; such procedures as tonsilectomies, appendectomies, normal child birth, and setting of simple fractures.
>
> Secondary care services are of a greater level of complexity requiring higher skill levels by the medical and support personnel and more complex support equipment than is required in primary care; such as gall bladder surgery, and simpler plastic surgery procedures. Tertiary care services are those of high level of complexity requiring very high skill levels of the medical and support personnel and extensive supporting equipment. Examples

TABLE VII

ANNUAL VISITS TO A PHYSICIAN PER PERSON

Age Cohort	Male	Female
Under 15[a]	3.18	2.12
15-17[b]	3.02	3.97
18-44[c]	3.02	3.97
45-64[c]	3.78	3.52
65+[c]	4.31	4.20

[a]Synthetic estimate.

[b]Application of rates for 18-44 cohorts to 15-17 group.

[c]Oklahoma Health Systems Agency: Unpublished data from Quality of Life in Oklahoma Survey 1976, University of Oklahoma.

> of such procedures would include heart surgery, neurosurgery, organ transplant, and complex restorative procedures (p. 5).

Strangely enough, although the health planning literature repeatedly refers to hospital care divided into primary, secondary, and tertiary levels, no information is available assigning percentages to each of these types of care.

In lieu of this information, at the suggestion of Mr. Jack Boyd, State Director of Health Planning, the distribution of hospital days between primary beds and specialized care beds for each disease category is accomplished through use of the Standards for Good Medical Care Based on the Opinions of Clinicians Associated with the Yale-New Haven Medical Center, with Respect to 242 Diseases (Schonfeld, Heston and Falk, 1975, Vol. II, Table 13, pp. 178-188). This source gives the referral percentages of patients from primary physician internists to specialists. While this method refers to change of physician rather than change of complexity of hospital care, the two concepts are generally equivalent in a rural area since specialists tend to locate their practices in urban areas. Therefore, referral to a specialist is equivalent to transfer of hospital care location from the rural to the urban hospital. Use of this method involves these assumptions.

1. Referral percentages are equivalent to the percentage of total hospital days for that diagnostic category which are spent in a specialized care facility.

2. Referral rates do not decrease as the distance to the appropriate specialist increases.

3. The different ailments within a diagnostic category are equally likely.

These assumptions are introduced because use of this source for this information requires it, and no better alternative is known to exist. Maternity and Tonsillectomy are not in this source so another method is used for them. The maternity figures are taken from Blue Cross data, and the tonsillectomy figure is assumed arbitrarily to be 100 percent primary cases. The resulting rates of primary vs. specialized hospital care by diagnostic category is found in Table VIII.

It is assumed that transfer ambulance calls all involve a switch from primary to specialized care, therefore, these are also generated in this portion of the model. Physician time accompanying hospital care and emergency room care is also introduced as part of the care regimen. These items are included through a matrix of accompanying services, shown in Table IX.

The physician's services are units of care appropriate for such an occasion, therefore one unit of physician's services for a primary bed day is the average treatment an M.D. or D.O. renders his patient in the hospital for primary care. The 0.9 for emergency room visits requiring physician's services indicates not all emergency room visits require a physician's presence. The value is based on personal experience and is quite arbitrary. The ambulance service for specialized care days reflects transfers to hospitals providing specialized care and is based on the experiences of Alfalfa County, which Doeksen, Frye, and Green (1975) estimated at 41 transfers, or approximately 2 percent of the specialized care days demanded according to the care regimen model.

TABLE VIII

PORTIONS OF TOTAL HOSPITAL DAYS REQUIRING PRIMARY VERSUS SPECIALIZED CARE BY DIAGNOSTIC CATEGORY

Category	Primary Care Portion	Specialized Care Portion
Infective and Parasitic	0.951	0.049
Neoplasms	0.353	0.647
Endocrine, Nutritional, and Metabolic	0.979	0.021
Blood and Blood Forming Organs	0.999	0.001
Mental Disorders	0.993	0.007
Nervous System and Sense Organs	0.601	0.399
Circulatory System	0.964	0.036
Tonsillectomy[a]	1.000	0.000
Respiratory System	0.873	0.127
Digestive System	0.818	0.182
Genitourinary System	0.670	0.330
Maternity Care[a]	0.902	0.098
Skin and Subcutaneous Tissue	0.776	0.224
Musculo-skeletal System and Connective Tissue	0.689	0.331
Congenital Anamolies	0.539	0.461
Certain Causes of Perinatal Morbidity and Mortality	1.000	0.000
Symptons and Ill-Defined Conditions	0.941	0.059
Accidents, Poisoning, and Violence	0.666	0.334

Source: Derived from Schonfeld, Heston, and Falk, 1975, Vol. II, Table 13, pp. 178-188.

[a]These categories are not found in Schonfeld, Heston, and Falk (1975). Maternity care rates are derived from Blue Cross data. Tonsillectomy is assumed to be 100 percent primary care.

TABLE IX

DEMAND FOR SERVICES ACCOMPANYING A UNIT OF A SERVICE

Basic Service	Primary Bed Day	Ambulance Trip	Emergency Room Visit	Physician's Services	Specialized Bed Day
Primary Bed Day	1.0			1.0	
Ambulance Call		1.0			
Emergency Room Visit			1.0	0.9	
Physician Visit				1.0	
Specialized Bed Day		0.02		1.0	1.0

Summary of the Demand Sector

The services included in this model are included because they comprise the entire emergency care armamentarium, which excludes nursing homes and dental care, and because the information necessary for more specific delineation is not available. It is apparent that even this level of specificity extends somewhat beyond the data, and further disaggregation would become entirely arbitrary. Similar criteria determined the number of locations considered, and here also further extension would provide more accurate modeling for some services. For a lower level region, such as a single county, disaggregation is a necessity.

Supply Sector

Beginning with an initial inventory of health resources for each supply location within the study area, the supply model determines how these resources should be employed to minimize the objective function subject to the constraint that demand must be satisfied. Since health resources have been carefully cataloged by the state's health planners, no data problems occur at this stage. The 1975 distribution of health resources for the area is shown in Figures 3-6. The exact locations of these resources are known, so the possible supply locations considered are the locations previously deemed satisfactory by those locating facilities at these points. Since the major health problems in rural areas are maintaining present medical facilities and retaining or replacing existing personnel, there is little justification for considering additional sites, although the model allows it.

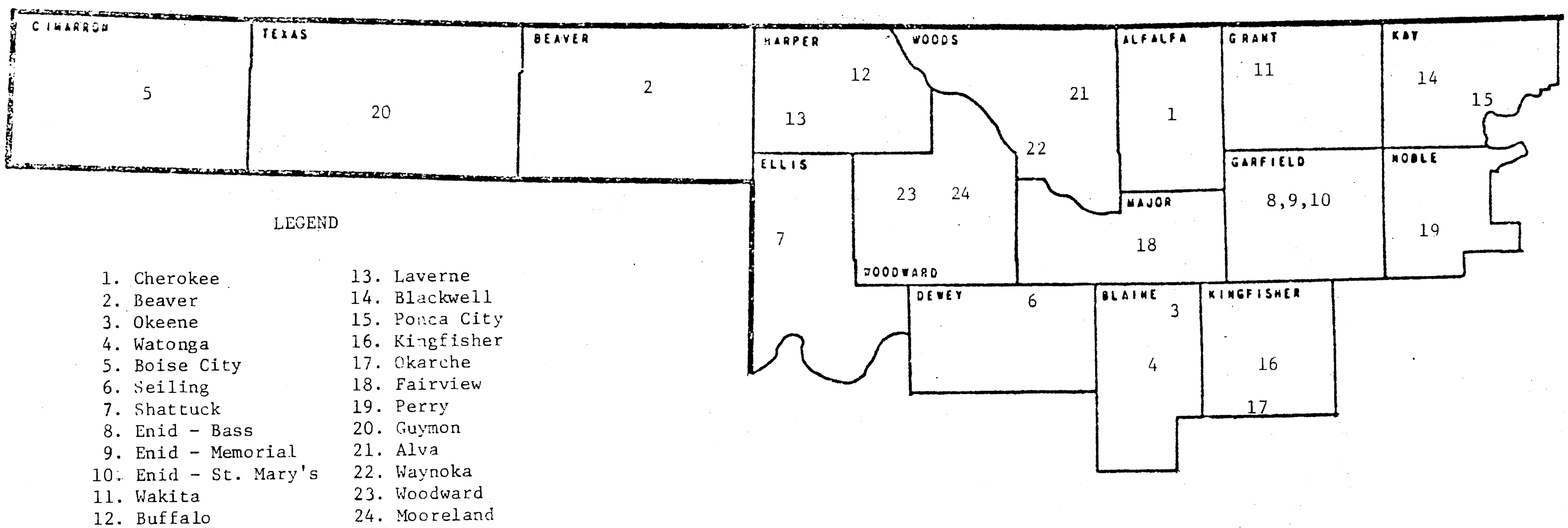
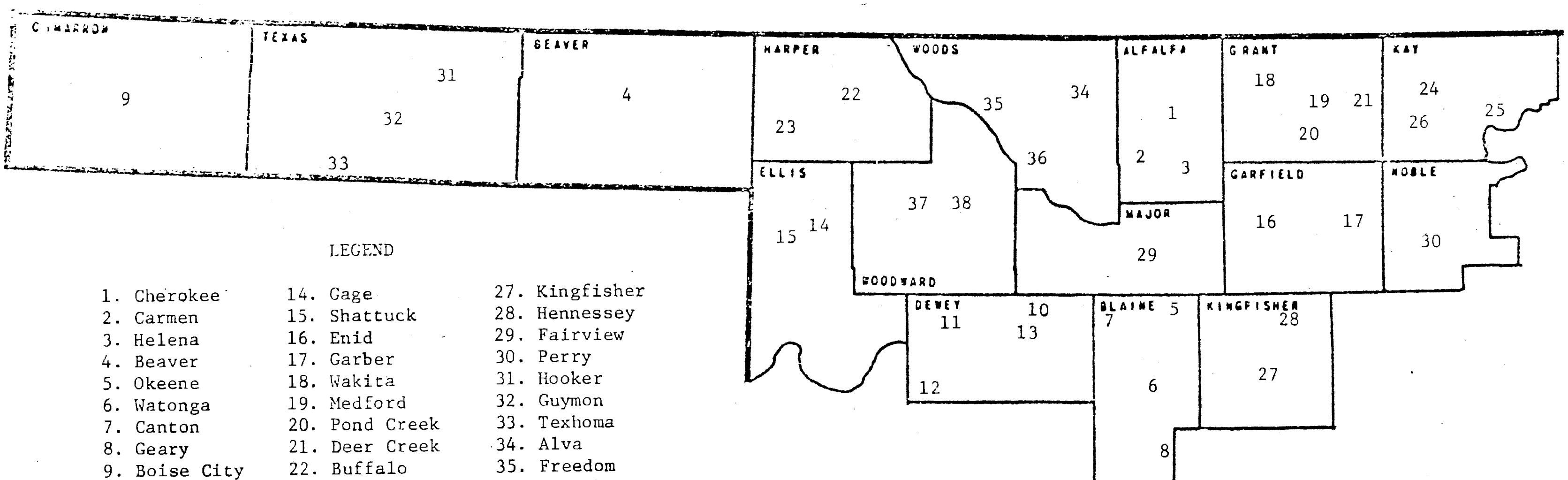


Figure 3. Map Showing Location of Hospitals in Study Area



LEGEND

1. Cherokee
2. Carmen
3. Helena
4. Beaver
5. Okeene
6. Watonga
7. Canton
8. Geary
9. Boise City
10. Seiling
11. Vici
12. Leedey
13. Taloga
14. Gage
15. Shattuck
16. Enid
17. Garber
18. Wakita
19. Medford
20. Pond Creek
21. Deer Creek
22. Buffalo
23. Laverne
24. Blackwell
25. Ponca City
26. Tonkawa
27. Kingfisher
28. Hennessey
29. Fairview
30. Perry
31. Hooker
32. Guymon
33. Texhoma
34. Alva
35. Freedom
36. Waynoka
37. Woodward
38. Mooreland

Figure 4. Map Showing the Location of Ambulance Services in the Study Area

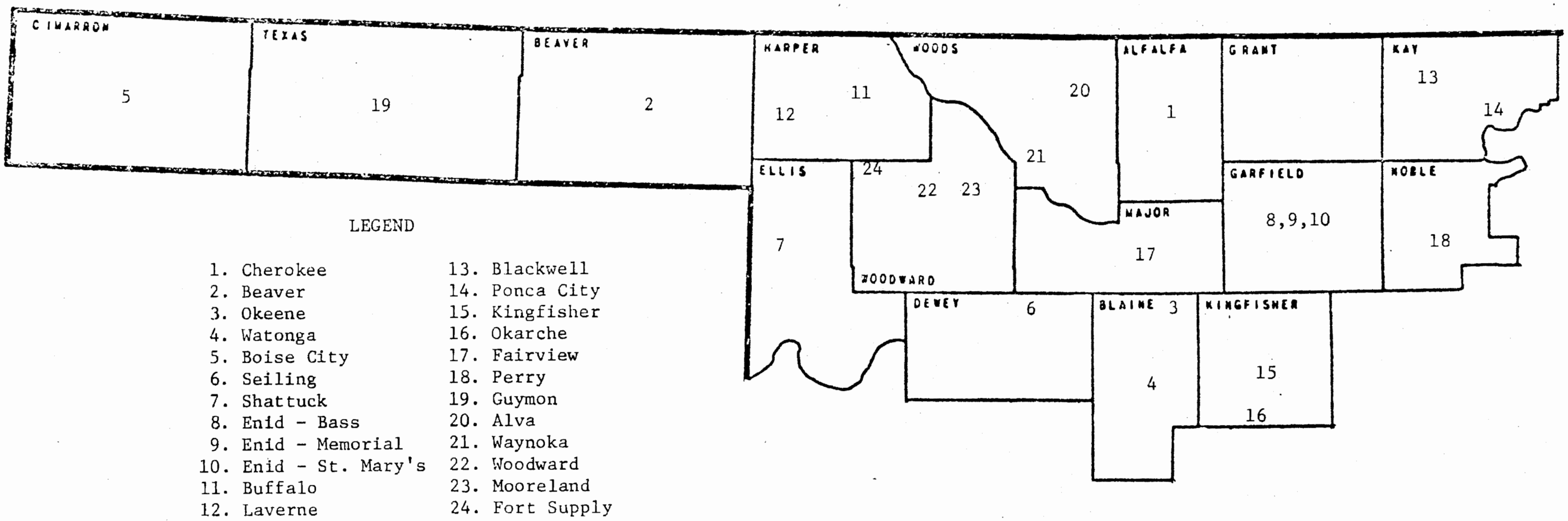
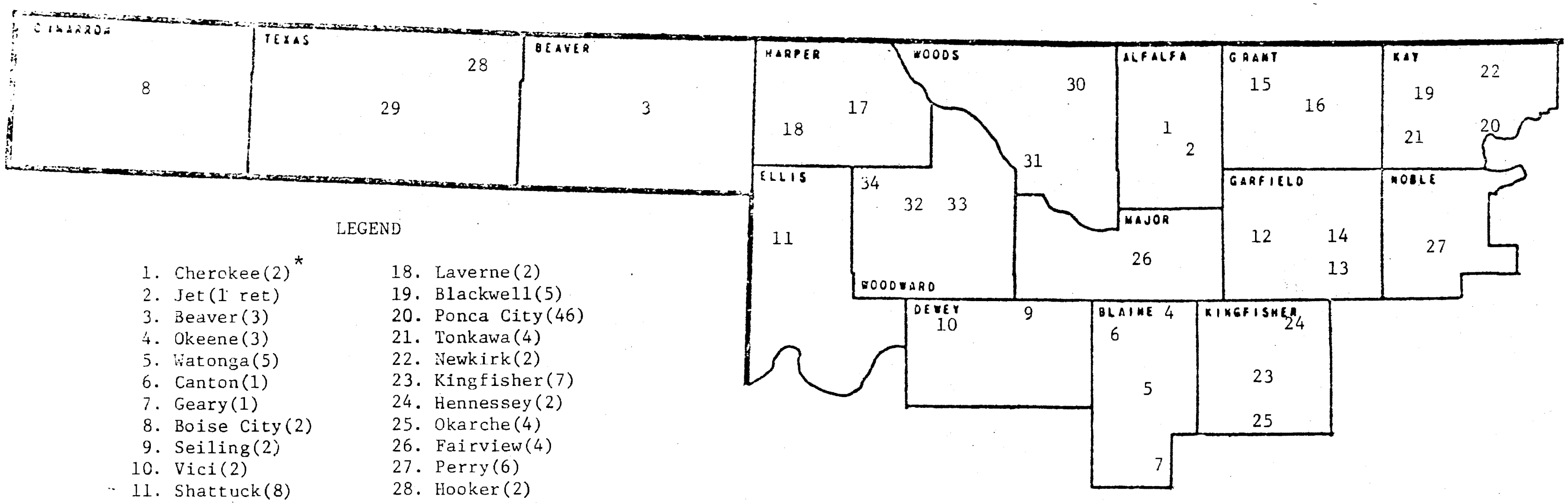


Figure 5. Map Showing the Location of Emergency Rooms in the Study Area



LEGEND

1. Cherokee(2)*
2. Jet(1 ret)
3. Beaver(3)
4. Okeene(3)
5. Watonga(5)
6. Canton(1)
7. Geary(1)
8. Boise City(2)
9. Seiling(2)
10. Vici(2)
11. Shattuck(8)
12. Enid(82)
13. Covington(1)
14. Garber(1)
15. Wakita(1)
16. Medford(2)
17. Buffalo(2)
18. Laverne(2)
19. Blackwell(5)
20. Ponca City(46)
21. Tonkawa(4)
22. Newkirk(2)
23. Kingfisher(7)
24. Hennessey(2)
25. Okarche(4)
26. Fairview(4)
27. Perry(6)
28. Hooker(2)
29. Guymon(10)
30. Alva(6)
31. Waynoka(2)
32. Woodward(11)
33. Mooreland(2)
34. Fort Supply(7)

*Value in parentheses is the number of doctors in that community

Figure 6. Map Showing the Location of Doctors in the Study Area

Costs

Resource requirements and costs of services are the primary gaps in supply data. These holes are filled in different ways for the different services considered. The hospital costs are based upon operating budgets for 43 Oklahoma hospitals of varying size. The ambulance costs are taken from Doeksen, Frye and Green (1975) and represent observed operating expense data. The emergency room charges and the specialized care charges are derived from the hospital operating budgets mentioned previously. Physician fees are based upon data from the American Medical Association (1974).

Hospital costs pose a particularly troubling problem. How can the differences in services be removed to lay bare the cost of the basic unit of service, the primary care day? Two approaches are used, neither completely satisfactory. Dividing the state's hospitals into four size categories, less than 51 days, 51-100 beds, 101-150 beds, and more than 150 beds, a sample of approximately 30 percent is taken from each. For each of these hospitals the annual operating budgets are examined with certain relevant financial statistics obtained for each. Group means for each of these statistics are found, as well as the variance of this mean. After dividing each hospital's budgetary items by the number of beds, and by the number of patient days, group means for per bed and per patient day financial data are found and the variance of these means. Selected portions of this information for the small hospitals, i.e. those of 50 beds or less, in Tables X, XI, and XII, is based on a sample of 22 hospitals of a total population of 65. Table X gives selected budget items for the small hospitals. In this hospital class, 56 percent of total costs are salary costs, 92 percent of all revenues

TABLE X

SELECTED FINANCIAL OPERATING FIGURES FOR A SAMPLE OF OKLAHOMA HOSPITALS OF 50 OR FEWER BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$334525.50	$120464.20	$21051.88
Non Salary Expenses	267929.10	114007.60	19923.56
Total Expenses	602454.70	226475.50	39578.02
Inpatient Revenues	645073.20	266886.10	46640.05
Outpatient Revenues	52832.68	30834.31	5388.49
Total Revenue	698905.90	293582.70	51305.44
Net Income	17687.45	32605.97	5698.10

TABLE XI

SELECTED FINANCIAL OPERATING FIGURES PER BED FOR A SAMPLE OF OKLAHOMA HOSPITALS OF 50 OR FEWER BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$10517.04	$2383.39	$ 416.51
Non Salary Expenses	8452.31	2661.14	465.05
Total Expenses	18969.35	4672.16	816.49
Inpatient Revenues	20160.14	5539.24	968.02
Outpatient Revenues	1633.51	732.97	128.09
Total Revenues	21793.66	6045.96	1056.57
Net Income	506.81	903.15	157.83

TABLE XII

SELECTED FINANCIAL OPERATING FIGURES PER PATIENT DAY FOR A SAMPLE OF OKLAHOMA HOSPITALS OF 50 OR FEWER BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 50.64	$ 7.97	$1.39
Non Salary Expenses	40.06	9.91	1.73
Total Expenses	90.07	15.01	2.62
Inpatient Revenues	95.25	16.27	2.84
Outpatient Revenues	7.66	2.96	0.52
Total Revenues	102.90	17.61	3.08
Net Income	1.78	5.50	0.96

are from inpatient activities, and a profit margin of 2.5 percent is shown.

Taking per bed figures, seen in Table XI, is more meaningful, since there is a 50 percent range in size within this small hospital group. This reduces the coefficients of variation considerably, from 37.6 percent to 21.4 percent for total expenses, and allows a more meaningful measure of expenses.

Even using costs per bed fails to remove differences in operating costs adequately. For this reason, the financial figures are divided by patient days, as shown in Table XII. When examined in this way, the coefficient of variation for total expenses is 16.5 percent, a decline of almost 23 percent from its per bed counterpart. Total revenue minus total expenses does not equal net income, as it theoretically should, primarily because of non-collectable revenues.

The sample hospitals in this group have an average size of 31.9 beds and an average occupancy of 212 days per year, with a range of 15-50 beds and 99-307 days per year. The range of net profit is from a $56,000 loss to a $72,000 profit.

Equivalent figures for the 51-100 bed days of hospital are in Tables XIII - XV. For this size category, salaries are 59 percent of the total expenses, inpatient services generate 94 percent of the revenues, and the hospitals show a profit margin of 4.7 percent. These figures are based on a sample of nine hospitals from a population of 26 or a 34.6 percent sample. The hospitals in the sample average 74.9 beds and an occupancy of 207.3 days per year per bed with a range for these characteristics of 58-99 beds and 135-284 days of occupancy per year. The profitability spread ranges from a $4,000 loss to a $180,000 profit.

TABLE XIII

SELECTED FINANCIAL OPERATING FIGURES FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 51 TO 100 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 873139.80	$271215.00	$ 74549.81
Non Salary Expenses	596917.10	226337.80	62214.31
Total Expenses	1470057.00	472744.10	129944.80
Inpatient Revenues	1638172.00	514613.60	141453.60
Outpatient Revenues	111955.50	64638.96	17767.55
Total Revenue	1750128.00	570815.90	156902.30
Net Income	83025.63	66263.06	18213.97

TABLE XIV

SELECTED FINANCIAL OPERATING FIGURES PER BED FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 51 TO 100 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$11726.04	$3544.53	$ 974.30
Non Salary Expenses	7949.06	2495.87	686.05
Total Expenses	19675.11	5720.50	1572.41
Inpatient Revenues	21981.00	6295.55	1730.48
Outpatient Revenues	1499.86	827.83	227.55
Total Revenues	23480.86	7005.72	1925.69
Net Income	1088.77	883.49	242.85

TABLE XV

SELECTED FINANCIAL OPERATING FIGURES PER PATIENT DAY FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 51 TO 100 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 57.37	$12.99	$3.57
Non Salary Expenses	39.49	14.30	3.93
Total Expenses	96.86	25.37	6.97
Inpatient Revenues	107.63	25.76	7.08
Output Revenues	7.25	3.69	1.01
Total Revenues	114.87	28.95	7.96
Net Income	5.22	3.82	1.05

As with the small hospitals, the coefficient of variation for total expenses decreases with the deflation by beds and patient days, but for this group the reduction is much less, from 32.2 to 26.2 percent. The average charge per patient day is $12.38 higher than the smaller hospitals, but the increase in expenses is only half this amount.

Tables XVI - XVIII show the financial operating information for the 101-150 bed class of hospitals. This class, with only 11 members, is very unprofitable according to the five hospital sample. With non-salary expenses comprising 51 percent of expenditures, this hospital size is apparently much more capital intensive than the two smaller classes, with unfavorable results. Inpatient revenues are 96 percent of the total, with outpatient revenue comprising a smaller portion of the total, than for the smaller size classes. The sample averages 115.4 beds and 194 days of occupancy per bed each year. The range of bed sizes is 101-148 beds and the occupancy range is 154-281 days per year. Only one of the five hospitals shows a profit, that only $4500, with one hospital losing $389,000, or over $20 per patient day.

Low occupancy and large non-salary expenses per bed, 69 percent higher than the 51-100 bed class, are the basis of the problem, with depreciation and interest amounting to nearly $2600 per bed. For this class, the coefficient of variation for total expenses decreases from 35.4 percent to 19.6 percent when rates per patient day rather than totals are considered.

The financial information for hospitals larger than 150 beds is in Tables XIX - XXI. From a population of 24 hospitals, seven are sampled, or 29.2 percent. These have an average size of 368 beds and an average

TABLE XVI

SELECTED FINANCIAL OPERATING FIGURES FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 101 TO 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$1514869.00	$ 545489.70	$188963.10
Non Salary Expenses	1579557.00	574719.20	199085.50
Total Expenses	3094427.00	1096682.00	379901.80
Inpatient Revenues	3214181.00	1573973.00	545240.10
Outpatient Revenues	141740.00	112763.00	39062.24
Total Revenues	3355920.00	1593013.00	551836.00
Net Income	168100.50	162192.50	56185.12

TABLE XVII

SELECTED FINANCIAL OPERARING FIGURES PER BED FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 101 TO 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$12905.29	$2677.28	$ 927.44
Non Salary Expenses	13442.29	3180.13	1101.63
Total Expenses	26347.57	5485.07	1900.08
Inpatient Revenues	26850.61	8224.45	2849.03
Outpatient Revenues	1260.82	1064.60	368.79
Total Revenues	28111.42	8219.16	2847.20
Net Income	1620.58	1563.17	541.50

TABLE XVIII

SELECTED FINANCIAL OPERATING FIGURES PER PATIENT DAY FOR A SAMPLE OF OKLAHOMA HOSPITALS WITH 101 TO 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 67.62	$12.00	$4.16
Non Salary Expenses	70.55	17.14	5.94
Total Expenses	138.17	27.08	9.38
Inpatient Revenues	137.50	19.89	6.89
Output Revenues	6.79	6.02	2.08
Total Revenues	144.29	19.96	6.92
Net Income	9.91	9.70	3.36

TABLE XIX

SELECTED FINANCIAL OPERATING FIGURES FOR A SAMPLE OF OKLAHOMA HOSPITALS LARGER THAN 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 6281097.00	$4757027.00	$1545778.00
Non Salary Expenses	5643385.00	4182762.00	1359172.00
Total Expenses	11924480.00	8815008.00	2864403.00
Inpatient Revenues	12015890.00	9615769.00	3124608.00
Outpatient Revenues	580195.80	618457.80	200965.50
Total Revenues	1259609.00	9929696.00	3226619.00
Net Income	98155.00	1507080.00	489720.20

TABLE XX

SELECTED FINANCIAL OPERATING FIGURES PER BED FOR A SAMPLE OF OKLAHOMA HOSPITALS LARGER THAN 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$16591.58	$3659.51	$1189.14
Non Salary Expenses	14514.75	3608.41	1172.54
Total Expenses	31006.33	6627.64	2153.63
Inpatient Revenues	31006.06	8411.25	2733.20
Output Revenues	1861.57	2081.37	676.33
Total Revenues	32867.63	9057.94	2943.34
Net Income	180.70	3670.09	1192.58

TABLE XXI

SELECTED FINANCIAL OPERATING FIGURES PER PATIENT DAY FOR A SAMPLE OF OKLAHOMA HOSPITALS LARGER THAN 150 BEDS

	Mean	Standard Deviation	Standard Deviation of the Mean
Salary Expenses	$ 72.44	$19.28	$ 6.26
Non Salary Expenses	67.03	32.73	10.63
Total Expenses	139.47	51.30	16.67
Inpatient Revenues	132.29	22.98	7.47
Outpatient Revenues	7.67	7.25	2.36
Total Revenues	139.96	23.67	7.69
Net Income	7.47	31.11	10.11

occupancy of 240 days per year. This widely diverse group, ranging in size from 152 beds to 735 and in occupancy from 97 days per year to 277, has only one sample hospital really unprofitable, losing $296,000, and only one hospital with an occupancy rate of less than 240 days per year.

From this summary data it appears that two distinct groups exist. The group of smaller hospitals has non-salary expenses per bed of around $8000 and the large hospitals have non-salary expenses per bed of about $14,000. This suggests the separation point for specialized care hospitals is about 100 beds with the economies of size perhaps existing, but occupancy being more important.

The major difference between primary care and secondary or tertiary care is the use of sophisticated services and specialists. To divide the costs between primary care and specialized care, cost per patient day is regressed on the number of services offered and the inverse of the occupancy rate with the following results.[1/]

$$\underset{}{EXPP} = \underset{(2.22)}{25.72} + \underset{(6.85)}{2.833}\ SER + \underset{(5.29)}{11664}\ BEDS/PD$$

$$R^2 = 0.726 \qquad D.W. = 1.77$$

where EXPP is the expenses per patient day, SER is the number of services the hospital offers, BEDS is the number of beds and PD is the number of patient days. The number of beds, number of services, and number of patient days are from the Oklahoma Health Planning Commision (1976b). The expenses per patient day are from the hospital budget study mentioned previously.

[1/] Value in parentheses is the t statistic.

By using this equation to generate the cost of a uniform primary care day, the average cost for a specialized care day is derived. This is done by utilizing information from the Oklahoma Blue Cross, given in Table XXII. This information is combined with the information in Table VIII as follows. To compute the average charge per day of specialized care, all disease categories with a specialized care percentage greater than 10 percent are used. Those categories with percentages smaller than 10 percent are excluded for sensitivity reasons. The average primary cost is found by substituting an occupancy of 214 days per year, the average for the 43 hospitals sampled, and 4.31 services, the average number for the hospitals with less than 100 beds, into the estimated equation, yielding an expected cost for one day of primary care of $92.44. For example, 35.3 percent of all neoplasm cases are primary cases and cost $92.44 per day, for 7.18 days. Then 218 x 92.44 or $229.22 of the $1012.23 average neoplasm bill is spent for primary days, the remaining $783.01 being specialized days. Dividing this by the average stay and the weight, 0.647, an average cost per specialized day for neoplasms of $168.55 is found. The identical procedure is used for the other eight categories having more than ten percent specialized care days. These costs are weighted by the estimated number of specialized care days in Oklahoma in these categories in 1975 and divided by the total of these days. The resulting cost per specialized care day is $216.53.

For the primary care days, each hospital's 1975 occupancy rate is substituted into (3.1), with 4.31 services assumed to simulate a homogeneous product. The cost per primary day derived thus is found in Table XXIII.

TABLE XXII

1975 HOSPITAL COSTS AND STAYS BY DISEASE CLASSIFICATION

Disease Classification	Cost per Procedure	Average Stay
Infective and Parasitic	$ 511.12	4.43
Neoplasms	1,012.23	7.18
Endocrine, Nutritional, and Metabolic	761.60	6.28
Blood and Blood-Forming Organs	699.99	4.83
Mental Disorders	899.97	10.97
Nervous System and Sense Organs	595.18	4.30
Circulatory System	1,192.52	7.92
Tonsillectomy	322.64	1.93
Respiratory System	616.51	4.98
Digestive System	907.79	6.83
Genitourinary System	684.28	4.92
Maternity Care	615.57	3.82
Skin and Subcutaneous Tissue	629.60	4.92
Musculoskeletal System and Connective Tissue	846.05	7.16
Congenital Anomalies	993.86	5.92
Certain Causes of Perinatal Morbidity & Mortality	828.78	8.67
Symptoms and Ill-Defined Conditions	617.30	4.85
Accidents, Poisonings and Violence	740.31	5.66

Source: Oklahoma Blue Cross (unpublished data).

TABLE XXIII

ESTIMATED COST PER DAY OF PRIMARY HOSPITAL CARE

Hospital	Cost
Alfalfa County Hospital	$113.77
Beaver County Memorial Hospital	114.11
Okeene Municipal Hospital	206.67
Watonga Municipal Hospital	95.69
Cimarron Memorial Hospital	110.33
Seiling Hospital*	100.60
Newman Memorial Hospital	103.66
Bass Memorial Hospital	84.84
Enid Memorial Hospital	109.85
St. Mary's Hospital	94.46
Community Health Center-Wakita	109.61
Harper County Community Hospital	87.42
Laverne General Hospital	112.42
Blackwell General Hospital	80.67
St. Joseph's Medical Center of Ponca City	103.39
Community Hospital-Kingfisher	99.97
Okarche Memorial Hospital	97.65
Fairview Hospital	88.32
Perry Memorial Hospital	117.57
Memorial Hospital-Guymon	96.99
Share Memorial Hospital	92.81
E.P. Clapper Memorial Hospital	118.23
Memorial Hospital-Woodward	111.49
Northwest Community Hospital	98.91
Oklahoma City Hospitals*	88.00
Wichita Hospitals*	88.00
Amarillo Hospitals*	88.00

*Hospitals for which costs are estimated synthetically.

As the cost of primary hospital care is dependent upon the occupancy, so also is the cost of specialized care. The $216.53 derived price for specialized care is adjusted for the observed occupancy of each hospital in 1975, relative to the 214 day average of the sample. The costs derived by this method are found in Table XXIV.

Ambulance charges have two components, a base charge and a mileage charge. Doeksen, Frye, and Green (1975) suggest $25 and $1 per one-way mile, respectively, as reasonable fees for a rural ambulance system. For Enid and Ponca City, the rates are undoubtedly higher so a base charge of $35 is used for them. The accuracy of these charges is less important than for hospitals because only one cohice is usually available.

Physician charges vary with community size. The rate structure shown in Table XXV illustrates this vividly. Examinations comprise 88.3 percent of physician office visits and follow-up visits, 11.7 percent (DeLorier and Gagnon, 1975, p. 19). Using these weights and inflating the fees by 12.8 percent, the inflation for the physician fees component of the Consumer Price Index in 1975, an average physician fee schedule for 1975 is found, 1975 being the year all charges in the study are based upon. Using this method, the average physician fee for a county with less than 10,000 people in 1975 is $15.01. The average fee for the other sized areas are $19.03, $19.28, $23.88, and $25.43, respectively.

Emergency room fees are estimated using another portion of the hospital budgets mentioned previously. In these, each hospital's outpatient revenues are divided by the average number of emergency room visits for different hospitals size classes (American Hospital

TABLE XXIV

ESTIMATED COST PER DAY OF SPECIALIZED HOSPITAL CARE

Hospital	Cost
Newman Memorial Hospital	$227.75
Bass Memorial Hospital	208.94
Enid Memorial Hospital	233.94
St. Mary's Hospital	218.56
St. Joseph's Medical Center of Ponca City	227.49
Oklahoma City Hospitals	212.10
Wichita Hospitals	212.10
Amarillo Hospitals	212.10

TABLE XXV

MEAN FEE FOR ANNUAL EXAMINATION AND FOLLOW-UP PHYSICIAN VISIT BY COUNTY SIZE, 1974

Population of the Area	Mean Fee per Examination	Mean Fee for Follow-Up Visit
Under 10,000	$14.21	$ 6.49
10,000-25,000	17.98	8.52
25,000-50,000	18.22	8.61
50,000-500,000	22.48	11.31
500,000-1,000,000	23.90	12.33

Source: American Medical Association (1974).

Association, 1976, p. 112). These figures are then adjusted for occupancy differences and group means for the four size classes are derived. These charges, shown in Table XXVI, are tested to see if the group means are different. The test shows no significant difference, with an F statistic of 0.241 distributed with 3 and 39 degrees of freedom. The overall mean is $37.78. Since the differences within groups outweigh the differences between groups, the single figure of $37.78 is used. This figure contains elements other than strictly emergency room charges, but no effort will be made to extract them, thereby introducing the assumption that any other services lumped into this charge are demanded proportionately to emergency room treatment and can be considered a part of the total health expenses, though not individually in this model.

Health Service Capacities

Hospital Capacity. For hospital capacity, combining specialized and primary bed days, assumption of Poisson distribution for patient arrivals allows the acceptable risk of turning patients away to govern the average capacity when the maximum capacity is known. Joseph and Folland (1972) derive capacity in the following manner. The probability that the hospital census will exceed $L + B\sqrt{L}$, for some constant B is the same for all relevant L, where L is the average daily census. This is true because:

1. The standard deviation of the Poisson distribution is $\sqrt{L}$.

2. The normal distribution approximates the Poisson distribution when the mean, L, is large.

TABLE XXVI

AVERAGE FEE FOR EMERGENCY ROOM TREATMENT FOR OKLAHOMA HOSPITALS

Hospital Size	Cost
50 beds or less	$37.45
51-100 beds	33.09
101-150 beds	40.95
151 + beds	42.60

If the administration has an acceptable probability of turnaway, then he chooses the size of his hospital such that $S = L + B^* \sqrt{L}$, where S is the hospital size and B^* is the constant associated with the administrator's conception of when the cost of an extra bed approximately offsets the cost of the expected turnaways prevented by having that bed.

Let $S = ADC + B\sqrt{ADC} + U$

where ADC is the average daily census and U is a stochastic error term.

Then $\frac{S-ADC}{ADC} = \frac{B}{\sqrt{ADC}} + \frac{U}{ADC}$

Using data for 1971 from Oklahoma hospitals, this equation is estimated as:[2/]

$$\frac{S-ADC}{ADC} = \underset{(17.18)}{3.779} \left(\frac{1}{\sqrt{ADC}}\right)$$

This estimate is larger than Joseph and Folland's 3.22 and between the values of 3 and 4 mentioned by the Commission on Hospital Care (1947). It has been a probability associated with it of 0.0001. Since this is the probability of exceeding the capacity, the expected occurrence of the daily census exceeding capacity for the average Oklahoma hospital in 1971 was once every 10,000 days, or once every 27 years. This value for B is much higher than the 3.0 which the Oklahoma Health Planning Agency uses in their estimation of bed need. A probability of 0.0013 accompanies 3.0, or approximately one occurrence every two years.

While Long and Feldstein (1967, p. 120) correctly note that the variation in demand is related to population size rather than hospital

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[2/]Value in parentheses is t statistic.

size, this distinction is weakened by recognition that average daily census is related to the subset of the population served by that facility. This segmentation of the population is similar to considering a hospital serving a small population rather than consideration of many hospitals serving a large population.

In a rural area, the distinction is unimportant and the tendency of families to concentrate their care in a single hospital creates effectively the same situation in an urban setting that exists in rural areas.

The capacity of the hospitals in the study area, using 3.0 for B^* as the Oklahoma Health Planning Agency does, is seen in Table XXVII. Initially, there is no limitation on the distribution of this capacity between primary and specialized days, but should the occasion arise, a minimum of 60 percent primary days shall be imposed. Emergency room capacity restrictions are not imposed. Instead, choice of emergency rooms is restricted to the facilities which are closest.

Physician Capacity. Physician capacities are not generally agreed upon. Schonfeld, et al. (1975, pp. 127-137) can be used to compute the average time spent for various types of physician visits. Each alternative is weighted equally for lack of a better weighting scheme. The results are:

Average office visit	31.6 minutes
Average home visit	28.6 minutes
Average emergency room visit	39.1 minutes
Average hospital inpatient visit	22.9 minutes

where the minutes are the physician's time spent. These all appear high, perhaps because they are based upon the physician's opinion of

TABLE XXVII

AVERAGE HOSPITAL CAPACITY ASSUMING POISSON DISTRIBUTED ARRIVALS AND A PROBABILITY OF TURNAWAY OF 0.0013

Hospital	Licensed Beds	Average Capacity
Alfalfa County Hospital	20	10.349
Beaver County Memorial Hospital	38	23.467
Okeene Municipal Hospital	80	57.292
Watonga Municipal Hospital	35	21.190
Cimarron Memorial Hospital	20	10.349
Seiling Hospital	19	9.671
Newman Memorial Hospital	114	86.154
Bass Memorial Hospital	152	119.241
Enid Memorial Hospital	104	77.577
St. Mary's Hospital	287	240.478
Community Health Center-Wakita	7	2.376
Harper County Communicy Hospital	25	13.840
Laverne General Hospital	34	20.438
Blackwell General Hospital	64	44.082
St. Joseph's Medical Center of Ponca City	231	189.682
Community Hospital-Kingfisher	38	23.467
Okarche Memorial Hospital	25	13.840
Fairview Hospital	23	12.425
Perry Memorial Hospital	28	16.000
Memorial Hospital-Guymon	58	39.214
Share Memorial Hospital	40	25.000
E.P. Clapper Memorial Hospital	24	39.130
Memorial Hospital-Woodward	90	65.686
Northwest Community Hospital	36	21.946

how much time he spends.

Radtke and Nordblom (1975a) use a figure of 7,537 office visits per physician per year. This is equivalent to 16 minutes per visit. This figure is not their estimate of capacity but rather of breakeven volume for a one-person clinic. This clinic budget only includes office visit fees, while hospital fees are part of a clinic's revenues. Therefore, the breakeven volume is much too high.

The 1972 national average patient visits per year per physician is 3,905. A 1972 Arkansas study (Grinstead, McCoy, and Green, 1976a) find an average of 3,704 patient visits per year per physician. Using utilization data from Oklahoma University's "Quality of Life in Oklahoma" Survey for physicians and 1975 populations projections, Oklahoma averaged 3,977 patient visits per physician.

Golladay, Manser, and Smith (1974) estimate physician capacity at 140 physician visits per week with no added efficiency in multiple physician practices except when physician extenders are used. Using a 46.7 week year, which Cordes (1973) finds to be the average time spent in routine activities for rural practices, yearly capacity of 6,538 patient visits is found. Cordes (1973) finds physicians in rural Washington average 6,328 office visits per year.

From these divergent estimates, one figure must be drawn. Since the three averages of less than 4,000 include many hospital based physicians without office practices, teaching physicians, and specialists who see few patients, a capacity of 6,500 is used, with part-time physicians seeing 2,000. Physicians practicing in non-hospital towns lose 500 visits per annum of capacity due to travel.

<u>Ambulance Capacity</u>. Since the demand for ambulance service has a stochastic element to it, those responsible for determining the number of ambulances required must decide the optimum number in light of uncertain demand. Without considering extreme requirements associated with a multiple injury automobile accident or some similar catastrophe, there is a certain probability that ambulance service will be required while all units are in use. This probability can be decreased by having a large fleet of ambulances in relation to the average number required. Such a fleet requires a large revenue to support its costs, and if its size is disproportionately large in relation to the population it serves, its revenues will be inadequate and a substantial subsidy will be required to keep it solvent.

Any number of ambulances has a probability of occasional excess demand. Capacity of an ambulance service represents the expected number of calls that can be handled per year for the decision maker's acceptable probability of excess demand. To find capacity, this excess demand probability must be related to average demand.

One method of doing this is with queuing theory. Initially, the general theoretical underpinnings of queuing theory will be considered and then they will be applied to this particular situation. These derivations are taken from Saaty (1961, pp. 38-40), but may be found in any introductory queuing theory text.

Assume that arrivals and departures at some service point are independent, letting $v(t)$ represent the average arrival rate and $u(t)$ the average departure rate. Then $v(t).\Delta t$ is the probability that a person will arrive in the interval $(t,t+\Delta t)$, and $u(t).\Delta t$ is the probability that service will be terminated in the interval $(t,t+\Delta t)$, given that a person is in the serving queue at time t.

In order to have k persons in the system at time $t+\Delta t$, one of three events must have occurred if Δt is short enough to make the probability of a multiple change in the queue negligible. Multiple change is defined as both the arrival of a person and the departure of a person in an interval length Δt, or some other combination of arrivals and departures involving two or more persons. The three events are then:

E_1: at time t there are k-1 persons in the system and during Δt one person arrives and none depart.

E_2: at time t there are k persons in the system and during Δt no one arrives or departs.

E_3: at time t there are k+1 persons in the queue and during Δt, no one arrives and one person departs.

The probability of k persons in the system at time t+ t is therefore the sum of the probabilities of these three events.

$$P_k(t+\Delta t) = P(E_1) + P(E_2) + P(E_3) \tag{3.2}$$

where

$$P(E_1) = P_{k-1}(t)(v(t).\Delta t)(1-u(t).\Delta t)$$

$$P(E_2) = P_k(t)(1-v(t).\Delta t)(1-u(t).\Delta t)$$

$$P(E_3) = P_{k+1}(t)(1-v(t).\Delta t)(u(t).\Delta t)$$

When Δt is small $(\Delta t)^2$ is extremely small and may be dropped. Doing this (3.2) becomes

$$P_k(t) + P_{k-1}(t)\ v(t).\Delta t + P_{k+1}(t)\ u(t).\Delta t - P_k(t)\ v(t).\Delta t$$

$$- P_k(t)\ u(t).\Delta t$$

This reduces to

$$\frac{P_k(t+\Delta t) - P_k(t)}{\Delta t} = P_{k-1}(t)\ v(t) + P_{k+1}(t) - P_k(t)(v(t) + u(t))$$

By definition

$$\lim_{\Delta t \to 0} \frac{P_k(t+\Delta t) - P_k(t)}{\Delta t} = \frac{dP_k(t)}{dt}$$

If there is a maximum queue length of N and a minimum of zero, then

$$\frac{dP_k(t)}{dt} = \begin{cases} P_1(t)\ u(t) - P_o(t)\ v(t) & \text{when } k=0 \\ P_{k-1}(t)\ v(t) + P_{k+1}(t)\ u(t) - P_k(t)\ v(t) + u(t) & \text{when } 0<k<n \\ P_{n-1}(t)\ v(t) - P_n(t)\ u(t) & \text{when } k=n \end{cases}$$

If $v(t) \to v$ and $u(t) \to u$, i.e. these average rates become constant with respect to time, then

$$\frac{dP_k(t)}{dt} \to 0$$

In this case the following series of equations results

$$0 = vP_{k-1} + uP_{k+1} - (v+u)\ P_k \qquad 0<k<n \tag{3.3}$$

$$0 = uP_1 - vP_0 \tag{3.4}$$

$$0 = vP_{n-1} - uP_n \tag{3.5}$$

(3.4) becomes

$$P_1 = \frac{v}{u} P_0$$

which when substituted into (3.3) yields

$$P_2 = (\frac{v}{u})^2 P_0$$

$$\vdots$$

$$P_k = (\frac{v}{u})^k P_0$$

At this point define $p = \frac{v}{u}$. Since

$$P_0 + P_1 + P_2 + \ldots + P_n = 1$$

$$1 = P_0(1 + p + p^2 + \ldots + p^n)$$

or $P_0 = \frac{1-p}{1-p^{n+1}}$ and $P_k = p^k(\frac{1-p}{1-p^{n+1}})$.

The average number of people in the system is

$$\sum_{x=0}^{n} P_x X = \sum_{x=0}^{n} (\frac{1-p}{1-p^{n+1}}) p^x X = (\frac{1-p}{1-p^{n+1}}) \sum_{x=1}^{n} p^x X$$

$$= (\frac{1-p}{1-p^{n+1}}) \sum_{x=1}^{n} p^x (\frac{1-p^{n+1-x}}{1-p})$$

$$= \frac{1}{1-p^{n+1}} \sum_{x=1}^{n} (p^x - p^{n+1}) = \frac{1}{1-p^{n+1}} (\sum_{x=1}^{n} p^x - NP^{n+1})$$

$$= \frac{1}{1-p^{n+1}} (\frac{p-p^{n+1}}{1-p} - Np^{n+1})$$

For $N \to \infty$, this becomes $\frac{p}{1-p} = L$.

The variance is derived similarly to be, in the infinite case, $L + L^2$.

The interesting application of queuing theory to ambulance demand is: given a certain average service time, and an acceptable probability, α, that the system will have two or more persons in it, i.e., that at least one person will desire service, but will have to wait until treatment of another is concluded, what value of v, the average arrival rate, corresponds to such parameters. From the Poisson tables (General Electric Company, 1962) Table XXVIII is compiled.

Recall that the mean queue length is $\frac{p}{1-p}$, where $p = \frac{v}{u}$, and where v is the average arrival rate, and u the average service rate. Then

$$L = \frac{p}{1-p} = \frac{v}{u-v}. \qquad (3.6)$$

Using Table XVIII to determine the acceptable mean, L, and knowing u, v may be derived, thereby yielding the number of calls per unit time which can be handled in order to attain the acceptable probability of

TABLE XXVIII

MEAN OF THE POISSON DISTRIBUTIONS ASSOCIATED WITH QUEUES OF VARIOUS LENGTHS OR GREATER FOR SELECTED PROBABILITIES OF SUCH LENGTHS

Probability	Queue Length 2	3	4	5
0.1000	0.5300	1.1000	1.7000	2.4000
0.0500	0.3550	0.8100	1.3500	1.9500
0.0250	0.2420	0.6100	1.0500	1.6000
0.1000	0.1485	0.4350	0.8200	1.2500
0.0050	0.1030	0.3370	0.6700	1.0500
0.0025	0.0720	0.2630	0.5500	0.9100
0.0010	0.0450	0.1905	0.4250	0.7300
0.0005	0.0315	0.1495	0.3550	0.6300
0.0001	0.0140	0.0860	0.2310	0.4400

having all the ambulances in use when one is required, or ambulance capacity.

For purposes of illustration, consider the following sample problem. A one ambulance community is willing to accept a probability of two patients requiring the ambulance simultaneously of 0.0025, or about one occurrence per year. This probability has an associated mean of 0.072, using Table XXVIII. An analysis of a year's calls for an ambulance operation serving a generally rural area, reveals an average service time of 30.6 minutes with a standard deviation of 23.7 minutes, hence a service rate u of 1.96 calls per hour. Substituting into (3.6) yields

$$0.072 = \frac{v}{1.96 - v}$$

$$(0.072)\ (1.96 - v) = v$$

$$0.141 = 1.072v$$

$$v = 0.132$$

or an associated mean rate of demand for service of 0.132 calls per hour, which translates to 3.16 calls per day, or 1,155 calls per year.

Doeksen, Frye and Green (1975, p. 4-5) indicate that the demand for ambulance service isn't uniform throughout the day and week. Weekdays and Saturday average 15.2 percent of the calls per week, while Sunday has only 8.7 percent. Similarly, a much higher percentage of the day's calls, 36.2 percent, occur from noon until 6 p.m. than during the other quarter periods of the day. This non-uniformity in service demand means an ambulance service planning to handle 1,155 calls per year with a single ambulance and a probability of overlapping demanders for the ambulances of 0.0025 will actually face a somewhat higher probability. If, instead of assuming a uniform demand rate throughout the week, Friday afternoon, the peak load period is considered, using the derived rate of 0.132 calls per hour, an average of 0.792 calls per Friday afternoon is derived. While this represents 3.57 percent of the total week's time, Doeksen, Frye and Green (1975, p. 4-5) indicate that it represents 5.97 percent of the week's ambulance demand, so an annual rate of 693 calls is implied is a probability of 0.0025 of multiple demand is applied to the peak period.

However, this does not represent a probability of 0.0025 for calls as a whole either. While the computation required to determine the number of calls consistent with such a probability is prohibitive, an estimate of this number may be made using a relatively simple procedure. The median intensity demand period for the week is an average of Monday and Thursday mornings, with 4.67 percent of the week's total calls occur for the six hour period. Using the previously derived rate of 0.132 calls per hour, an annual rate of

$$\left(\frac{(0.132)(6)}{.04666}\right) \text{ x } \left(\frac{365}{7}\right) = 885 \text{ calls per year}$$

is obtained. This method assumes that the probability of a queue of two or more for the higher demand portions of the week of greater than 0.0025 is offset by the probabilities of less than 0.0025 for the lower demand portions of the week. This probability and method are used to estimate ambulance capacities.

The average time out for ambulance service in a town with a hospital is 30.6 minutes. Cherokee is assumed to represent this average ambulance service with an average trip of 17 miles for towns with less than 2,500 people and Watonga the average ambulance service for towns larger than 2,500. Any mileage difference in average rural trip is added to the service times. For example, Hennessey has an average trip mileage of 60 miles compared to the 17 miles for Cherokee, so the average service time for Hennessey is calculated to be 73.6 minutes. As a result, service times vary for each community and hence, capacity for a single ambulance community also varies.

Support Personnel Requirements. Certain support personnel are required to staff hospitals and doctor's offices. For the purposes of this model it is assumed that one nurse is required per doctor, and one nurse for every two hospital beds. No distinction is made here between registered nurses (RN) and licensed practical nurses (LPN) but 50 percent of each is about average. Using this criterion the demand for each county given in Table XXIX, along with the 1971 numbers of such personnel. Nurses are also needed for nursing homes, school, and state hospitals, and other services excluded from this model. Even recognizing this, the rule of thumb fails miserably. Some counties, for example Blaine, fall substantially short, while others, Alfalfa for one, have considerably more than apparently are needed. Similar anomalies are seen when RN to LPN ratios are examined. In the 11 comprehensive health planning areas in 1971 the RN to LPN ratio varied from 0.63 to 2.50 (Oklahoma State Health Planning Agency, 1972a).

Apparently the two skills are substitutable over a wide range with the mix depending on local or regional factors. Similarly, many tasks done by nurses in some areas are apparently done by non-nurses in others.

New Facilities

In shortage areas, purchase of new facilities may be required. For this reason, initial costs for certain facilities are necessary.

TABLE XXIX

NURSES NEEDED IN HOSPITALS AND PHYSICIANS OFFICES IN 1975 AND NUMBERS AVAILABLE IN 1971

County	Number Needed	Number Available*
Alfalfa	13	29
Beaver	22	24
Blaine	68	41
Cimarron	12	17
Dewey	13	31
Ellis	65	43
Garfield	355	331
Grant	7	33
Harper	38	27
Kay	204	276
Kingfisher	45	50
Major	16	14
Noble	20	31
Texas	41	37
Woods	40	42
Woodward	83	104

*Source: Oklahoma State Health Planning Agency (1972b).

The types of facilities considered are additional hospital capacity, new clinics, and ambulance service.

Hanson, Doeksen, and Green (1977) estimate an appropriate construction cost to be $62,500 per bed for a new 35 or 75 bed facility. For additions to existing facilities, the cost is substantially less, averaging $24,768 for four expansions of 20-40 beds in Oklahoma from 1974-76. The average operating budgets for existing hospitals can be used to estimate cash flows. The expense budgets for hospitals of less than 50 beds and for 51-100 beds are shown in Table XXX. The background of these budgets is given at the previous presentation of selected portions of them. The average revenue schedule for these two classes of hospital is presented in Table XXXI. Table XXXII presents an average income and expense statement.

With the elimination of the Hill-Burton plan, no federal matching funds are available so the local community must finance any hospital construction or expansion themselves. This financing can add up to 20 percent to the cost of a project.

The second investment offered is a new clinic in a community. Three types of clinics are allowable. The first is a traditional clinic situation in which, although the community builds the facility, the physicians are charged rent on the facility and practice as independent businessmen. The other two varieties are publicly operated clinics with salaried physicians established under the auspices of some federal program. These options are selected not because they represent the universe of choices available but rather because they show enough variety to offer choice. These budgets are a composite of information from different sources.

TABLE XXX

SUMMARY OF AVERAGE OPERATING EXPENSES FOR SELECTED OKLAHOMA HOSPITALS, BY SIZE CATEGORY, 1975

Expense Item	50 Beds or Less	51-100 Beds
Salary Expenses		
Inpatient Services	$143,908	$342,481
Outpatient Services	3,880	18,266
Radiology	11,884	24,813
Laboratory	18,345	38,422
Other Ancillary	8,949	204,442
Pharmacy	2,446	12,710
Central Services	4,450	9,021
Dietary	29,702	59,285
Housekeeping, Laundry, and Maintenance	26,891	74,228
Administration	57,873	135,948
Other	359	163
Benefits	25,836	85,262
Total Salary	$334,526	$873,140
Non-Salary		
Medical Supplies	$ 19,250	$ 37,671
Pharmacy and Drugs	26,726	56,007
Inpatient Services	5,893	13,892
Outpatient Services	1,353	10,731
Radiology	29,906	56,799
Laboratory	34,866	56,128
Other Ancillary	28,465	74,895
Dietary	25,604	60,121
Housekeeping, Laundry, and Maintenance	30,322	82,524
Administration	35,716	63,855
Interest and Depreciation	29,777	78,660
Other	553	5,632
Total Non-Salary	$267,929	$596,917
Total Expenses	$602,455	$1,470,057

TABLE XXXI

SUMMARY OF AVERAGE PATIENT REVENUES FOR SELECTED OKLAHOMA HOSPITALS, BY SIZE CATEGORY, 1975

Revenue Source	50 Beds or Less	51-100 Beds
Inpatient Revenues		
Room and Board	$288,375	$676,911
Operating Rooms	14,666	58,282
Delivery Rooms	3,199	11,177
Anesthesiology	13,995	44,517
Radiology	46,283	101,863
Laboratory	90,451	201,671
Electrocardiology	13,758	28,126
Physical Therapy	1,315	13,917
Ambulance	136	0
Medical & Surgical Supplies	44,252	104,136
Pharmacy	78,667	214,836
Transfusion Service	336	0
Oxygen	19,224	79,411
Blood and Plasma	1,534	6,276
I.C.U. and C.C.U.	3,799	25,144
Nursery	4,802	15,062
I.V.'s	5,595	42,707
Emergency Room	1,185	5,215
Other	13,520	8,922
Total Inpatient Revenues	$645,073	$1,638,172
Total Outpatient Revenues	$52,833	$111,956
Total Patient Revenues	$697,906	$1,750,128

TABLE XXXII

SUMMARY OF AVERAGE INCOME AND EXPENSE STATEMENTS FOR SELECTED OKLAHOMA HOSPITALS, BY SIZE CATEGORY, 1975

Income & Expense Entry	50 Beds or Less	51-100 Beds
Total Patient Revenues	$697,906	$1,750,128
Less Allowances	84,322	253,239
Net Patient Revenues	613,584	1,496,889
Less Total Operating Expenses	608,932	1,469,325
Net Income from Patient Services	4,651	27,563
Plus Other Income	16,461	55,462
Total Income	21,113	83,026
Less Other Expenses	3,425	0
Net Income	17,687	83,026

Doeksen, Stackler, Dunn, and Sheets (1977) present a budgeting procedure by which the costs of a community clinic may be estimated. The procedure is general allowing several options for financing, operation and rental arrangements. Although many variations can be generated using such a procedure, the primary function of this model is not to examine thoroughly the economics of alternative clinic organizations.

The budgets are calculated using Doeksen, Stackler, Dunn, and Sheets (1977), with reference to two budgets for clinics obtained from Noel H. Green, Regional Program consultant for the Rural Health Program of the Public Health Service in Dallas Texas, and Radtke and Nordblom (1975a). The first budget is for a community clinic constructed and financed using community funding, and is found in Table XXXIII. It is assumed that financing is arranged through both local and federal sources. It is for 2 physicians with staff, who rent an equipped office from the community for its costs less finance charges. The building is assumed to be depreciated over 25 years, and the equipment over 8 years.

A second clinic is owned entirely by the community, with the two physicians employed by the clinic rather than being risk bearing entrepreneurs. The same building and equipment depreciation schedule is used for all three clinic varieties, and the staffing of this clinic is similar to the staffing of the first, and most doctor's offices in the region. Its budget is found in Table XXXIV.

The third type of clinic is a publicly owned and operated clinic with two physicians and a physician's assistant, all salaried. This clinic has greater capacity and, therefore, is not directly comparable

TABLE XXXIII

CAPITAL AND OPERATING BUDGET FOR A RURAL COMMUNITY OWNED CLINIC RENTED TO THE TWO PHYSICIANS STAFFING IT

Category		Amount
Start-Up Costs		
Building		$ 87,000
Equipment		20,000
Total		$107,000
Finance Arrangements		
Rural Health Initiative Grant		$ 30,000
FHA Loan at 5 1/2 25 years		70,000
Contributions		10,000
Total		$110,000
Receipts		
Rent		$ 12,000
Variable Costs		
Utilities		$ 3,050
Cleaning and Maintenance		2,050
Total		$ 5,100
Income over variable costs		$ 6,900
Ownership Costs		
Insurance		$ 250
Interest		3,850
Depreciation		
Building	$3,480	
Equipment	2,500	
Total Depreciation	$5,980	5,980
Total Ownership Costs		$ 10,080
Net Returns		($3,180)

TABLE XXXIV

CAPITAL AND OPERATING BUDGET FOR A COMMUNITY OWNED AND OPERATED CLINIC EMPLOYING TWO PHYSICIANS

Category		Amount
Start-Up Costs		
Building		$ 87,000
Equipment		20,000
Total		$107,000
Finance Arrangements		
Rural Health Initiative Grant		$ 50,000
FHA Loan at 5 1/2%		60,000
Contributions		10,000
Total		$120,000
Receipts		
Office Visits (6000 per physician)		$200,000
Hospital Changes (275 patients per physician)		45,200
Total Potential Receipts		$245,200
Less Non-Payments (10%)		24,580
Total Receipts		$221,220
Variable Costs		
Salaries		
Physicians	$100,000	
Registered Nuse	10,000	
LPN	8,500	
Receptionist/clerk	5,000	
Total Salaries	$123,500	$123,500
Benefits		17,290
Utilities		3,250
Cleaning and Maintenance		2,040
Audit		1,500
Office Supplies		1,000
Medical Supplies		18,750
Total Variable Costs		$167,330
Income over variable costs		$ 53,890

TABLE XXXIV (Continued)

Category		Amount
Ownership Costs		
Insurance		$ 3,500
Interest		3,300
Depreciation		
Building	$3,480	
Equipment	2,500	
Total Depreciation	$5,980	5,980
Total Ownership Costs		$ 12,780
Net Returns		$ 41,110

to the previous two. The percent of visits which a physician's assistant can handle is undecided, but 20 to 40 percent is the range discussed. For this clinic, 33 percent is used. The budget for the clinic is found in Table XXXV.

It is apparent that once established, such clinics are quite profitable. These budgets do not reflect the start up problems associated with initial entry into a market, nor do they reflect the problems of operation at low volumes. The amounts allocated for initial working capital is probably insufficient to weather many lean years.

Doeksen, Frye, and Green (1975) present a system for estimating the annual costs of supplying ambulance service. Of the several alternatives presented, one is shown in Table XXXVI. This budget is a volunteer system where volunteers make all calls and are paid five dollars per call or ten cents per mile, whichever is greatest.

Summary of the Supply Sector

The difficult problems of the supply sector are determining average capacity when demand is irregular across time, and determining costs, revenues, and resource requirements for the various services considered. As illustrated previously, on many occasions, a rough approximation based only on experience must substitute for actual figures. Hopefully, as health planners recognize this difficulty these data deficiencies will be alleviated, but in the interim little recourse is seen.

Interaction Sector

The interaction model combines the demand sector with the supply sector in the manner which minimizes the objective function. This

TABLE XXXV

CAPITAL AND OPERATING BUDGET FOR A RURAL COMMUNITY OWNED AND OPERATED CLINIC EMPLOYING TWO PHYSICIANS AND A PHYSICIAN ASSISTANT

Category		Amount
Start-Up Costs		
Building		$130,000
Equipment		30,000
Total		$160,000
Financial Arrangements		
Rural Health Initiative Grant		$100,000
FHA loan at 5 1/2%		70,000
Contributions		10,000
Total		$180,000
Receipts		
Office Visits		$300,000
Hospital Charges		67,800
Total Potential Receipts		$367,800
Less Non-Payments (10%)		36,780
Total Receipts		331,020
Variable Costs		
Salaries		
Physicians	$100,000	
Physician's Assistant	18,000	
Registered Nurse	10,000	
LPN	8,500	
Receptionist/clerk	5,000	
Lab assistant	5,000	
Total salaries	$146,500	$146,500
Benefits		20,510
Utilities		4,550
Cleaning and Maintenance		3,060
Audit		1,500
Office Supplies		1,500
Medical Supplies		28,100
Total Variable Costs		$205,720
Income over variable costs		$157,677

TABLE XXXV (Continued)

Category		Amount
Ownership Costs		
Insurance		$ 4,700
Interest		3,850
Depreciation		
Building	$5,200	
Equipment	3,750	
Total Depreciation	$8,950	8,950
Total Ownership Costs		$ 17,500
Net Returns		$140,177

TABLE XXXVI

EXAMPLE OPERATING COST BUDGET FOR A RURAL AMBULANCE SERVICE

Category		Amount
Capital Expenditures		
Depreciation		
Vehicle	$3,225	
Community System	800	
Interest		$ 1,440
Insurance		500
Total		$ 1,940
Operating Expenses		
Vehicle		
Gasoline	$1,296	
Tires	240	
Oil	64	
Filter	56	
Lubrication	28	
Tuneup	72	
Miscellaneous	120	
Two-Way Ratio	78	
Vehicle Total	$1,954	$ 1,954
Communication System at Station		252
Medical Expenses		
Linen	$ 335	
Medical equip. maint.	33	
Bandages, etc.	56	
Medical Total	$ 424	424
Total Operating Expenses		$ 2,630
Labor Costs		
Volunteer Fees		$ 5,382
Bookkeeping and billing		670
Total Labor Costs		6,052
Other Expenses		
Storage		$ 300
Malpractice insurance		500
Total Other Expenses		$ 800
Total Expenses		$11,422

Source: Doeksen, Frye, and Green (1975, pp. 12-13).

interaction is limited to the choices offered the demanders. Since travel cost, both in time and money, are important determinants in decisions between alternative facilities, the computation of distances to facilities is quite important, as is the price per mile charged for certain types of costs. Each of these matters is dealt with in the interaction sector.

A realistic re-creation of actual behavior depends heavily on the choices offered the health care user. For hospitals, these choices are taken from the Patient Origin Study by the Oklahoma State Health Planning Commission (1973). The choices generally are limited to the nearest hospital, the nearest regional hospital, usually Enid, the nearest tertiary hospital, Oklahoma City or Amarillo, and perhaps one nearby hospital of slightly larger size.

For ambulances and emergency rooms, the choice is viewed as more urgent than hospital or physician choice so only the nearest supplier is allowed for each demand point except when two suppliers are approximately equally distant. The supply points chosen are all emergency room facilities rated 3 or better in the Oklahoma Directory to Emergency Transportation and Medical Services, (The American College of Surgeon's Committee on Trauma, 1971). A rating of 3 is defined there as

> Stand-by Emergency Service: A facility with full emergency department. Physician is on call and may not be at hospital when patient arrives (p. III-1).

Of the hospitals in the region only the Wakita hospital does not carry a 3 rating, it being rated 4. Additionally, the Western State Hospital in Fort Supply has a 3 rated emergency room and is undoubtedly viewed as an alternative for emergency care by those living in the vicinity. Where a county has more than one ambulance or emergency room the county is divided into approximate market shares according to proximity. The average mileage is calculated for these subsections and a constraint put on maximum market shares, such that the sum of these market share limits is 105-110 percent of the total.

Physician choice is limited to physicians within the demander's county and to physicians in those other counties in which hospital choice is allowed. Physicians who supply office visits are required also to service their patients who are hospitalized in their county and answer emergency room calls. This is important for physicians located in communities without hospitals such as Garber, since this removes part of the advantage stemming from their presence in the small town.

Travel distances are computed as the highway mileage between locations using the most direct paved road. To compute the distance traveled for the rural populace, it is assumed that they are uniformly distributed throughout the county. It is further assumed that the available routes run perpendicularly, hence diagonal routes are unavailable. This makes the distance from P to O is Figure 7 $P_x + P_y$ rather than $\sqrt{P_x^2 + P_y^2}$, the distance via a diagonal route. The average distance from O for the rectangle of length ℓ and width w is

$$\int_0^w \int_0^\ell \frac{(x + y)\, dx\, dy}{wl} = \frac{w + \ell}{2}$$

It is further assumed that if no one will go to Tulsa if Oklahoma City is closer or to Oklahoma City if Tulsa is closer.

The assumption that distance is the sum of the vertical and horizontal distance rather than the direct distance has a precedent in Abernathy and Hershey (1972). They compute distance within a block as

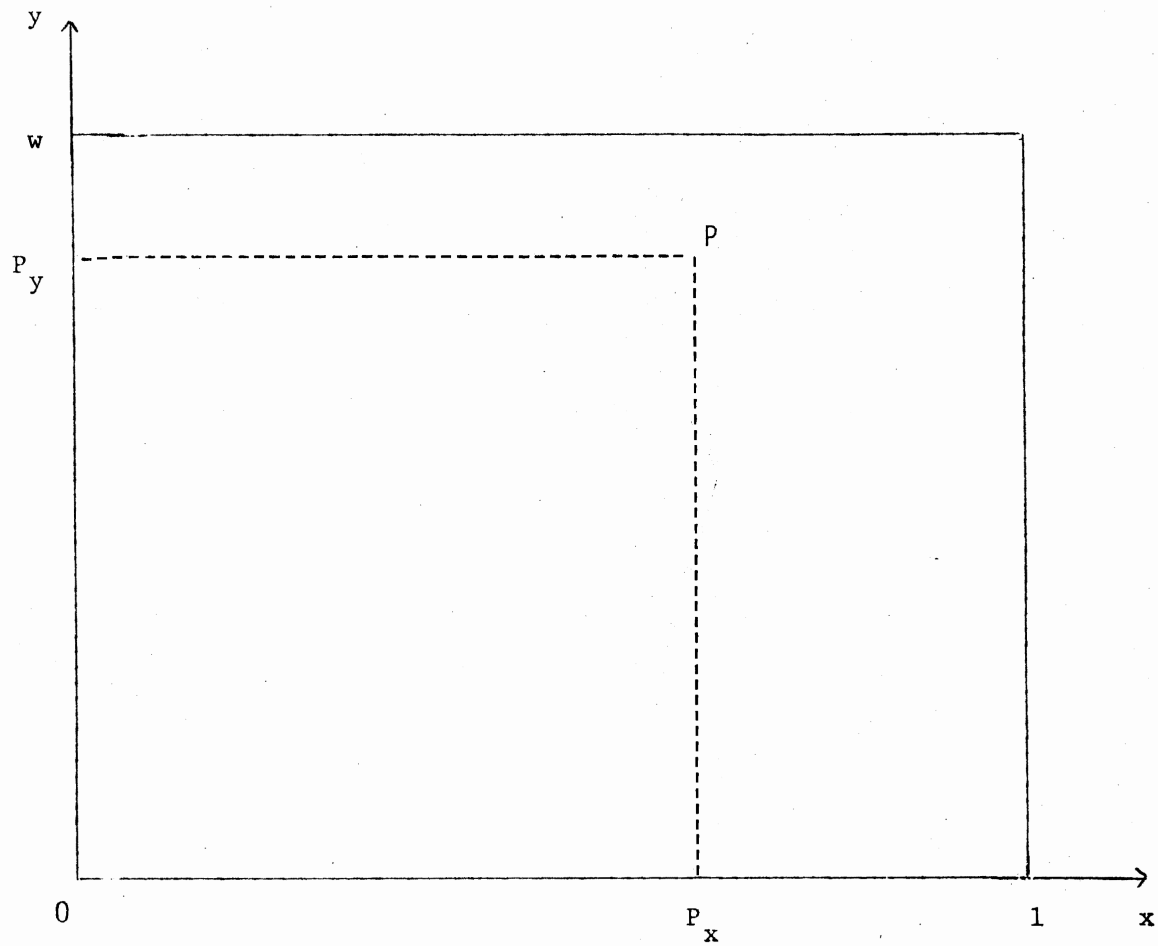

Figure 7. Travel Distance Illustration

the average distance from the center of the block to the border as is done above.

For physician mileage it is assumed that:

1. A physician on a regular hospital visit sees five patients, so 20 percent of the mileage between the physician's office and the hospital is assessed for each patient day of primary care.

2. In a small town (< 2,500 population) a physician lives one half mile from his office.

3. In a large town (2,500-10,000 population) a physician lives one mile from his office.

4. In a small city (10,000-50,000 population) a physician lives two miles from his office.

5. In a major city (50,000+ population) a physician lives four miles from his office.

6. For towns with hospitals, physicians office are one mile away, except in large cities where they are two miles away.

7. For emergency room visits, no multiple usage of trips is assumed so the entire mileage is assessed and one half of the trips are from home.

8. For physician office visits ten percent of the home to office mileage is assessed.

It is assumed that the ambulance will always go to the nearest emergency room so the ambulance mileage is computed for the destinations for each ambulance location as listed in Table XXXVII.

Travel cost is assumed to be $0.15 per mile. Ambulance emergency calls cost $1.00 per mile as do ambulance transfer calls. Physician's travel costs are included in their fee.

TABLE XXXVII

ASSUMED DESTINATION FOR EACH AMBULANCE LOCATION

Ambulance Location	Hospital Destination
Cherokee	Cherokee
Carmen	Cherokee
Helena	Cherokee
Beaver	Beaver
Okeene	Okeene
Watonga	Watonga
Canton	Okeene
Geary	Watonga
Boise City	Boise City
Seiling	Seiling
Vici	Seiling
Leedey	Seiling
Taloga	Seiling
Shattuck	Shattuck
Gage	Shattuck
Enid	Enid
Garber	Enid
Wakita	Enid
Medford	Enid
Deer Creek	Blackwell
Pond Creek	Enid
Laverne	Laverne
Buffalo	Buffalo
Kingfisher	Kingfisher
Hennessey	Enid
Blackwell	Blackwell
Tonkawa	Ponca City
Ponca City	Ponca City
Fairview	Fairview
Guymon	Guymon
Hooker	Guymon
Goodwell	Guymon
Texhoma	Guymon
Alva	Alva
Waynoka	Waynoka
Freeman	Alva
Woodward	Woodward
Mooreland	Mooreland

Summary of the Interaction Sector. The choices included in the interaction sector are selected on the basis of observed behavior and a logical approach to the patient's thought process. The fundamental items in the choice of health facilities are urgency, degree of services required, and cost. In an emergency the nearest facility will be chosen whenever possible. In a non-emergency a patient will travel only to get more specialized care than is available locally or when the local facility is clearly inferior. The use of observed occupancy in the cost function includes partially a quality measurement. Hospitals that are strongly rejected by the local populace have high costs making them unattractive to a cost minimizing patient. A facility that is very expensive for those services it offers may be avoided by the demanders.

Objective Functions

Choice of facilities to satisfy his health care needs is based on many interacting factors for the typical patient. Morrill and Earickson (1968) identify nine general characteristics of hospitals which affect patient travel distances. Inclusion of these characteristics would represent substantial progress in quantification of quality differences in hospitals. Yet this would still exclude the differing responses to such characteristics by various segments of the population. Lacking the data and expertise to generate such an objective function, a lesser goal is accepted. Rather than use a single, all powerful objective function, several simple objective functions will be tried, all supportable from some perspective of the health facility choice.

While these objective functions will be evaluated to their descriptive ability, they may be used to evaluate the system's efficiency in a prescriptive manner. For example, the present system could be compared to the minimum cost system where the minimum cost system is used as a norm.

The most straight forward of these objective functions is cost minimization, where the total cost of health care for the region is minimized. This includes all charges for the five services and a charge for patient mileage. This objective function is appropriate for the guidelines of health planners, such as the Oklahoma Health Systems Agency, since these are the actual costs borne. Indirect payments through insurance intermediaries are based on actuarial risks, with a net cost difference of administrative costs and profits.

A second objective function which concentrates more on the consumer's view of his options is the minimization of patient travel. This objective function minimizes total travel by the patient and his family figuring four person-trips per primary hospital day, two person-trips per ambulance trip, two person-trips per emergency room visit, two person-trips per physician office visit, and one-half person-trips per specialized hospital day.

The third objective function is a gravity travel function in which the squared distance between points is substituted for the distance in the travel minimization function and the sum of these squared distances weighted by the number of trips is minimized. This function makes long trips particularly unattractive.

The patient's variable costs are minimized rather than his total costs for the fourth objective function. For computational ease a coinsurance plan is assumed under which the patient pays 25 percent of all direct health costs and his entire travel costs.

A fifth objective function maximizes the profit of the regional hospital system. This profit is calculated using estimated profit per patient day for the four classes of hospitals. The following regression using the hospital budget data as its basis provides the coefficients.[3/]

$$NET/PD = \underset{(5.91)}{29.91} - \underset{(-5.72)}{5325}\ BEDS/PD - \underset{(-3.52)}{11.77}\ D$$

$$R^2 = 0.525$$

Where NET is the net profit in 1972 for each hospital, PD is the number of patient days, BEDS is the number of beds and D is a dummy variable, equal to 1.0 when BEDS $\geq$ 100, zero otherwise. Models where each class was considered individually was estimated, but with respect to net profits only two classes exist. The implications of this regression are interesting. A small hospital has a break-even volume of 178 days per year while a large hospital must be occupied 294 days per year. Despite higher bills per patient day the recovery rate of fixed costs per patient day is lower for large hospitals.

These objective functions will be used to optimize the system and each of their findings will be compared and contrasted both with each other and the observed performance of the system for 1975. On the basis of these comparisons, recommendations concerning their usefulness, both absolutely and relatively, can be made.

[3/] Values in parenthesis are t statistics with 39 degrees of freedom.

Summary

A successful model for health care should have no surprises. People should prefer local facilities unless a clearly superior alternative is reasonably accessible. The test of the model is its ability to forecast future usage through proper selection of choice criteria, accurate separation of heterogeneous products, and adequate inclusions of important underlying relationships. Whether the model outlined here satisfies these requirements will be seen later.

CHAPTER IV

MODELING THE PRESENT SITUATION

The reliability of a model's estimates are best measured by testing in a known situation. Such an opportunity is available through modeling the area health care system for 1975 because usage data for health facilities are compiled and published annually. With this observed performance as a check, the model is tested for 1975 with comparisons on the following pages. The model will first be evaluated for cost minimization and then other objective functions' estimates will be compared to these and the actual performance. Following the flow through the system as done in Chapter III for its development, the performance of the model is evaluated.

Minimum Cost and the Present Situation

Population Projections

Population predictions for each of the demand points are generated for 1975 using the population projection model. These predictions and corresponding predictions by the Oklahoma Employment Security Commission are given in Table XXXVIII. The overall totals are very close, less than 0.5 percent difference, while individual figures vary more. The poorest performance is for Woods County where the model is 8.6 percent higher than the official estimates. With the exception of Major County, which is underestimated by 6.34 percent, all other estimates are within

TABLE XXXVIII

POPULATION PREDICTIONS FROM THE POPULATION MODEL COMPARED WITH OFFICIAL PREDICTIONS

Locations	Model's Predictions	Official Predictions
Alfalfa County	6,864	7,100
Beaver County	5,981	5,900
Rural Blaine County	8,125	NA
Watonga	3,786	NA
Blaine County Total	11,911	12,300
Cimarron County	3,967	4,000
Dewey County	5,366	5,200
Ellis County	5,002	5,100
Rural Garfield County	11,380	NA
Enid	45,591	NA
Garfield County Total	56,971	58,200
Grant County	6,720	6,800
Harper County	4,937	5,100
Rural Kay County	10,694	NA
Blackwell	8,343	NA
Ponca City	25,458	NA
Tonkawa	3,223	NA
Kay County Total	47,828	47,400
Rural Kingfisher County	9,184	NA
Kingfisher (city)	4,116	NA
Kingfisher County Total	13,300	12,700
Rural Major County	4,717	NA
Fairview	2,963	NA
Major County Total	7,680	8,200
Rural Noble County	4,742	NA
Perry	5,307	NA
Noble County Total	10,049	10,400
Rural Texas County	9,425	NA
Guymon	8,408	NA
Texas County Total	17,833	18,200

TABLE XXXVIII (Continued)

Locations	Model's Predictions	Official Predictions
Rural Woods County	4,138	NA
Alva	7,372	NA
Woods County Total	11,510	10,600
Rural Woodward County	7,072	NA
Woodward (city)	9,113	NA
Woodward County Total	16,185	16,000
TOTAL	232,104	233,200

Source: Oklahoma Employment Security Commission, Oklahoma Population Projections, Oklahoma City, August, 1976.

five percent of the official estimate. The aggregate totals are different by only 0.47 percent. The estimates should not be very close since different migration rates are used, but for later years there is little reason to prefer official estimates over those generated by the population model.

The demand model with this population distribution yields the demand for services found in Table XXXIX. Additional facility demands not in Table XXXIX are automobile accident ambulance calls, ambulance transfers, and physician's time supporting each activity. The aggregate mix of hospital days is 88 percent primary and 12 percent specialized. Automobile accidents require 1,030 ambulance calls and inter-hospital transfers require 105,000 miles of ambulance transfer calls. Physicians also must visit patients for each of the 260,488 primary care days, the 73,596 specialized care days, and must treat 31,429 emergency room patients.

Hospital Usage

The utilization of the 27 hospitals in the region in 1975 as reported (Oklahoma Health Planning Commission, 1976b) and as indicated by the model is shown in Table XL. These utilization rates should be examined on a county wide basis rather than on an individual hospital basis because the availability of population distribution information only by counties and large cities makes lesser breakdowns more dependent on the simplifying assumptions than on differences in the population. An example of this can be seen in the three Enid hospitals. Since Memorial Hospital's low occupation rate makes its cost per patient day higher than the two other Enid hospitals, it is excluded entirely

TABLE XXXIX

DEMAND FOR VARIOUS HEALTH SERVICES BY DEMAND AREA

LOCATION	HOSPITAL BEDS	AMBULANCE	EMERGENCY ROOM	PHYSICIANS	SPECIALIZED CARE
ALFALFA	9667.61719	264.273320	1032.67383	24174.5117	2737.59985
BEAVER	6384.50000	149.949341	899.808105	20470.6172	1804.25806
BLAINE	10102.1680	263.396484	1222.56616	25169.1406	2854.89966
CIMARRON	3970.35669	93.451248	596.762451	13485.0664	1119.39453
DEWEY	6346.47656	175.496902	807.269775	15679.3789	1939.02612
ELLIS	6475.14453	168.024673	752.348389	17472.6719	1834.48706
GARFIELD	12730.3633	320.586670	1712.19556	38988.8086	3588.33643
GRANT	9095.76562	241.435715	1011.15576	23599.4141	2574.72729
HARPER	5560.35547	137.115082	742.717773	16974.0430	1569.18921
KAY	12620.4766	312.659668	1608.82275	36839.7969	3567.11548
KINGFISHER	9427.77344	230.353500	1381.76416	31173.1094	2652.43530
MAJOR	5577.25781	139.789307	709.463623	16299.5586	1575.48218
NOBLE	5367.84766	131.180923	713.376465	16318.9141	1514.60229
TEXAS	8939.49219	206.951324	1418.32788	31891.9766	2514.03296
WOODS	5634.04687	146.650162	622.191895	14526.5195	1594.81445
WOODWARD	8418.85156	213.146027	1063.97144	24480.5430	2377.51562
WATONGA	4350.71484	111.788635	569.677979	12969.0781	1229.03052
ENID	47826.4258	1154.74658	6859.75781	155514.812	13512.8125
BLACKWELL	7923.38672	255.290985	1255.51929	28785.1445	2810.51733
PONCA CITY	28113.0664	680.809570	3847.51636	87760.9375	7958.22656
TONKAWA	3914.54810	105.041565	484.511719	11146.8867	1106.04541
KINGFISHER (CIT	5038.74609	133.657333	619.483887	14213.0117	1425.73682
FAIRVIEW	3577.98218	94.339798	445.690674	10235.3867	1011.67749
PERRY	6723.31250	180.525208	798.241211	16381.0000	1902.00488
GUYMON	7426.06250	165.690552	1265.14941	28221.8594	2088.12256
ALVA	7797.44922	195.901611	1109.26294	25250.1875	2198.69336
WOODWARD (CITY)	8977.78516	210.255997	1370.77930	30838.0195	2535.45044
TOTAL	260467.375	6482.96828	34920.9609	796859.750	73596.0625

TABLE XL

ACTUAL AND ESTIMATED HOSPITAL UTILIZATION FOR 1975

Hospital Locations	Actual	Estimated
Cherokee	3,076	3,777[c]
Beaver	5,818	5,850
Okeene	5,530	4,275
Watonga	7,068	7,734[c]
Boise City	3,222	3,777[c]
Seiling	0[d]	3,530[c]
Shattuck[a]	20,231	6,644
Enid-Bass[a]	37,794	43,523[c]
Enid-Memorial[a]	16,867	0
Enid-St. Mary's[a]	59,220	71,412
Wakita[b]	1,139	867[c]
Buffalo[b]	5,892	3,806
Laverne[b]	8,216	1,755
Blackwell[b]	17,467	16,090[c]
Ponca City[a]	41,158	47,992
Kingfisher	7,144	8,565
Okarche	4,883	3,264
Fairview[a]	5,324	4,535[c]
Perry	4,101	5,840[c]
Guymon	11,455	14,313[c]
Alva	8,501	9,125[c]
Waynoka	3,486	1,960

TABLE XL (Continued)

Hospital Locations	Actual	Estimated
Woodward	14,270	12,844
Mooreland	6,886	8,010[c]
Oklahoma City[a]	large	33,780
Wichita[a]	large	0
Amarillo[a]	large	13,350

Source: Oklahoma Health Planning Commission (1976).

[a]Hospital offering both primary and specialized care.

[b]Hospital where actual usage exceeds capacity in model.

[c]Constrained solution.

[d]The Seiling Hospital was not open in 1975.

from the solution. With a more minute delineation of the county and the relationships of the physicians to specific hospitals, such a solution might be avoided. For the three Enid hospitals combined, the estimated utilization is somewhat higher than the actual utilization, 123,575 and 113,881, respectively.

Counties with close estimates are Beaver, Woods, Woodward, Blaine, and Kingfisher. Major and Grant Counties are constrained from reaching actual utilization by the capacity criterion, indicating a shortage of beds in the county.

Besides Garfield, counties with overestimation of usage are Alfalfa, Cimarron, Noble, Kay, and Texas. Alfalfa and Cimarron Counties lower actual utilization probably reflect an overestimation of the number of hospitalized patients two physicians can handle. Noble County, with Ponca City, Enid, and Stillwater all in adjacent counties, reflects a quality difference not reflected in costs. Except for overestimation of total number of patient days, no explanation for the difference in utilization for Texas County can be discerned. According to the Patient Origin Study (Oklahoma State Health Planning Agency, 1973) 77.2 percent of all discharges in 1972 for Texas County were from the Guymon hospital. The observed 11,455 is much less than 77 percent of the 20,968 patient days estimated.

The Garfield County and Kay County estimates are misleading because of the combining of all specialized care days. These hospitals, in fact, cannot satisfy all specialized care needs and many of those patients routed to Enid and Ponca City can not be treated there satisfactorily.

A more perplexing problem is the large estimated underutilization of Harper County hospitals. Observed patient days for Harper County's two hospitals in 1975 are 14,108 compared to only 7,129 total patient days estimated in the demand model. No source of patients of this magnitude from Oklahoma is indicated in the Patient Origin Study, and no likely source is apparent in the adjacent areas of Kansas.

The Shattuck hospital, a unique situation anyway with its 114 beds in a county of 5,000 people, has a larger actual utilization than the model reflects. The failure of the model to replicate this special situation is not considered serious.

For the study area's hospitals as a whole, utilization is overestimated by 13,557, this difference is due largely to insufficient flows to Oklahoma City. Figures 8 and 9 illustrate patient movements in the model for primary days and specialized care days, respectively. Since the choices offered are based on observed behavior, these movements are similar to those illustrated in the Patient Origin Study, except multiple destination movements are replaced by single destination movements.

Ambulance Usage

The demand for ambulances from individual facilities is given in Table XLI. The capacity problem never arises at the probability of 0.0025, so the actual probability of a patient waiting because the ambulance is in use is lower than this. In most instances, the percent of capacity used is much less than 50 percent. This figure is approached only in the larger cities. The ambulance decision process is more dependent on response time than cost, so capacity

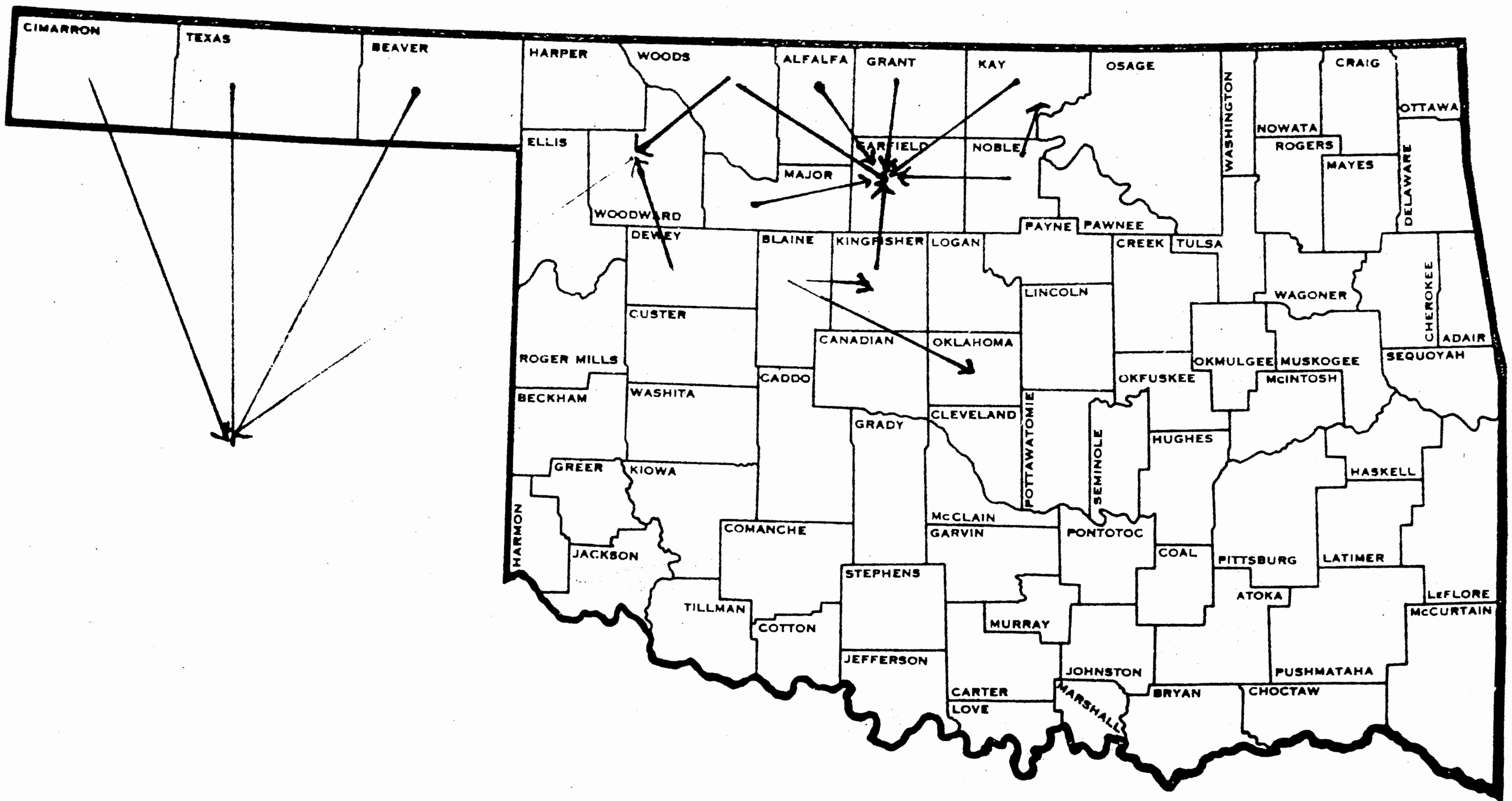

Figure 8. Out of County Movements for Primary Hospital Care

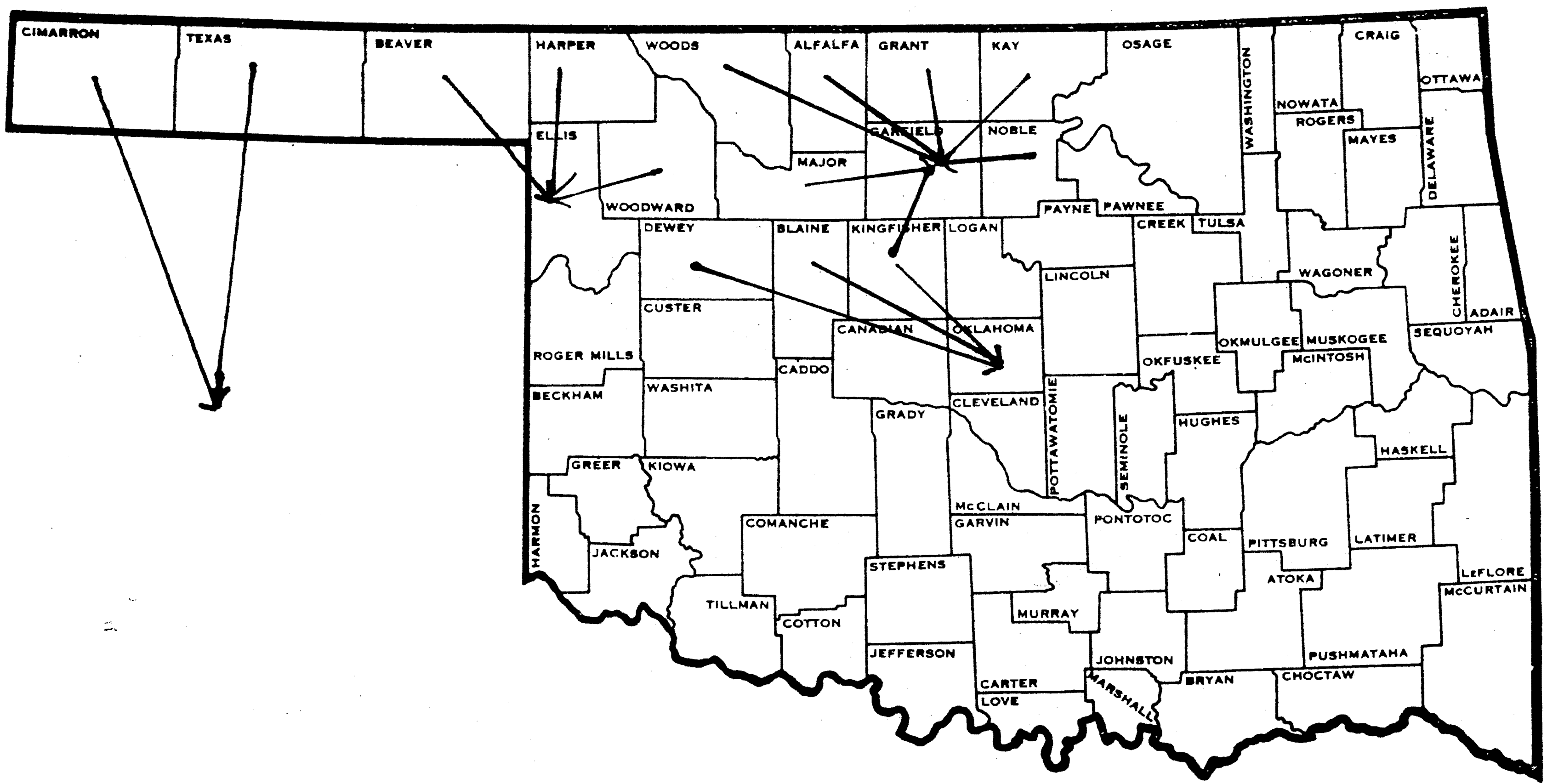

Figure 9. Out of County Movements for Specialized Hospital Care

TABLE XLI

ESTIMATED UTILIZATION OF AMBULANCE SERVICES BY LOCATION, 1975

Location	Emergency	Transfer
Cherokee	218	55
Carmen	58	
Helena	15	
Beaver	164	36
Okeene	50	13
Watonga	273	69
Canton	50	
Geary	47	
Boise City	105	22
Seiling	98	39
Vici	49	
Leedey	29	
Taloga	20	
Gage	89	
Shattuck	89	37
Enid	1,664	
Garber	137	
Wakita	64	51
Medford	39	
Pond Creek	51	
Deer Creek	103	
Buffalo	90	
Laverne	60	83
Blackwell	440	201
Ponca City	954	
Tonkawa	175	
Kingfisher	321	82
Hennessey	91	
Fairview	263	51
Perry	350	68
Hooker	60	
Guymon	321	92
Texhoma	70	
Alva	302	76
Freedom	42	
Waynoka	41	
Woodward	343	75
Mooreland	166	24

over-utilization is not a problem in rural areas. With few exceptions, rural counties have areas inadequately served by ambulance service using a response time criterion but the sparse population makes the costs of alleviating this prohibitive.

The division of ambulance calls between stations within a county not containing a city is suspect since the rural population is assumed to be uniformly distributed. However, an indication of the total business for each ambulance can be derived by the local decision maker using the aggregate county demand given in Table XXXIX and the proportion of the county's population in each ambulance service area. This involves an assumption of uniform composition of the population in all areas of the county. Such an assumption may be better than an assumption of uniform distribution as assumed herein. Since ambulances rarely cross county lines on emergency calls, the information gained by studying them on a regional scale is small.

Emergency Room Usage

A similar argument can be made for emergency room service, and since a limitation to local markets as service areas is imposed in the interaction model, little analysis of results is required. The utilization of the emergency rooms in the regions is given in Table XLII. Once again, for rural counties with two hospitals, the distribution of demand between facilities is very dependent upon the uniformly distributed population assumptions.

Physician Usage

The estimates for utilization of physicians, found in Table XLIII, indicate that substantial excess physician capacity exists in the area.

TABLE XLII

ESTIMATED EMERGENCY ROOM UTILIZATION, 1975

Hospital	Number of Encounters
Alfalfa County Hospital	1,033
Beaver County Memorial Hospital	900
Okeene Municipal Hospital	367
Watonga Municipal Hospital	1,425
Cimarron Memorial Hospital	597
Seiling Hospital	807
Newman Memorial Hospital	752
Bass Memorial Hospital	0*
Enid Memorial Hospital	9,583
St. Mary's Hospital	0*
Harper County Community Hospital	483
Laverne General Hospital	260
Blackwell General Hospital	1,864
St.Joseph's Medical Center of Ponca City	5,332
Community Hospital - Kingfisher	1,794
Okarche Memorial Hospital	207
Fairview Hospital	1,155
Perry Memorial Hospital	1,512
Memorial Hospital - Guymon	2,683
Share Memorial Hospital	1,607
E.P. Clapper Memorial Hospital	124
Memorial Hospital - Woodward	1,796
Northwest Community Hospital	532
Western State Hospital	106

*Alternate solutions.

TABLE XLIII

ESTIMATED PHYSICIANS OFFICE VISITS, 1975

Location	Number
Cherokee	12,590
Jet	0
Beaver	19,500*
Okeene	8,252
Watonga	25,780
Canton	6,000*
Geary	0
Boise City	12,590
Seiling	11,767
Vici	0
Shattuck	16,928
Enid	215,620
Covington	6,000*
Garber	6,000*
Wakita	2,890
Medford	12,000*
Buffalo	10,862
Laverne	5,849
Blackwell	32,500
Ponca City	119,975
Tonkawa	24,000*
Newkirk	12,000*
Kingfisher	28,550*
Hennessey	12,000*
Okarche	4,663
Fairview	15,117
Perry	19,467
Hooker	12,000*
Guymon	35,710
Alva	30,417
Waynoka	2,800
Woodward	40,418
Mooreland	11,970
Fort Supply	2,394
Oklahoma City	18,374
Wichita	0
Amarillo	18,093

*Constrained solution.

These estimates also indicate that this excess capacity is not uniformly distributed, but rather some locations are operating at or near capacity, while others are operating at only half of capacity. The urban areas, such as Enid, have specialists whose capacities are lower, and many semi-retired physicians, so the apparent excess capacity is overstated. The effect of these factors is not enough to explain this overcapacity, however. Although Cordes (1973), Radtke and Nordblom (1975), and others indicate capacity is somewhat greater than 6,000 annual visits, Oklahoma physicians as a group average far fewer visits than this, and even omitting specialists rich areas of Oklahoma City and Tulsa, average capacity utilization is low. The size of a physician's income is large enough that should he desire to work less, he may do so without substantial reduction in his standard of living. The model indicates that for the study area 53.6 percent of physician capacity is used, or 3,487 annual visits per physician.

On a county by county basis, the results are as follows: Alfalfa, Beaver, Cimarron and Grant Counties have high utilization, i.e. over 80 percent. Blaine, Dewey, Harper, Texas, Woods, and Woodward Counties have medium utilization, 60-80 percent. Ellis, Garfield, Kay, Kingfisher, Major and Noble have utilization of less than 60 percent. Recalling that Ellis and Harper Counties are underestimated in the hospital portion, it is likely that physician usage is also underestimated and these counties belong in a higher group. Similarly Alfalfa, Texas, Cimarron, and Noble Counties were overestimated in the hospital model, indicating potential overestimation of physician visits.

Dividing the counties into two groups, those having a city larger than 2,500 and those which do not, Table XLIV is formed. A Pearson's

TABLE XLIV

DISTRIBUTION OF PHYSICIAN CAPACITY UTILIZATION BY CATEGORY OF COUNTY"S LARGEST COMMUNITY

Utilization Rate	Size of Largest Community	
	<2,500	>2,500
> 80%	4	0
60 - 80%	2	4
< 60%	1	5

Chi-Square Test of Association (Hays and Winkler, 1970, pp. 195-205) has a value of 7.196 with 2 degrees of freedom, with an observed significance level of 0.03. This means that counties with no city are short of physicians, and the physicians in such counties must work much harder than their urban counterparts in order to serve the needs of their populations. This increase in practice size means a larger potential income at fixed fees or lower fees required to obtain a fixed income.

Summary of Results Under Minimum Cost Objective

Several aggregate calculations are made in this model of the 1975 health care system for the area. These values are interesting mainly for comparison purposes with other objective functions. Cost of medical care in 1975 for the five services modeled is estimated as $76,506,000. When this cost is decreased through a 25 percent coinsurance scheme for all costs except travel, an estimate of the variable costcost to the patient of $28,700,000 is derived for 1975. The hospitals netted a $4,449,000 loss. Patients traveled 85,099,000 miles to receive their medical service and physicians traveled 683,000 miles to provide it. Ambulances traveled 123,000 miles on emergency calls and 61,000 on transfer calls. Hospitals paid $23,812,000 in salaries to their employees. The area requires 631 nurses for hospital and physician's office duties, the distribution of which is shown in Table XLV.

As a whole, the solution gained by minimizing total cost closely resembles the actual situation for 1975. The situations where it differs can generally be remedied by greater disaggregation of the

TABLE LXV

ESTIMATED NUMBER OF NURSES REQUIRED BY COUNTY IN 1975
BY HOSPITALS AND PHYSICIAN PRACTICES

County	Number
Alfalfa	7
Beaver	11
Blaine	23
Cimarron	7
Dewey	7
Ellis	32
Garfield	233
Grant	3
Harper	10
Kay	132
Kingfisher	23
Major	9
Noble	11
Texas	27
Woods	20
Woodward	37

problem, i.e. better data. In particular those services distributed at several locations with a single county require division of the county into several demand areas rather than treatment as a unit as is done in this study. Minimizing total cost as an objective function is compared to alternative objective functions in the following section.

Other Objective Functions and the Present Situation

Four other objective functions are used for comparison purposes. These are patient travel, a gravity approach to patient travel, patient variable costs, and net hospital income. The results are summarized in Table XLVI.

Minimizing Patient Travel

When patient travel is minimized, differences in costs of medical care are ignored. Under this objective, patient travel is 83,497,000 miles, a 1.9 percent reduction from the minimum cost solution. Cost rises to $76,751,000 (Table XLVI), a 0.3 percent increase. In most instances hospital usage is unchanged from the minimum cost solution. The exceptions occur where a nearby facility is expensive and a distant facility is cheaper.

In terms of primary days, the only change occurs in Kingfisher. Since Blaine County residents are no longer deterred by the high costs of the Okeene hospital, they satisfy their primary hospitalization needs locally. This frees space in the Kingfisher hospital, allowing more Kingfisher County residents to satisfy their demand locally. Additionally, some of the Kingfisher demand is transferred to Oklahoma City.

TABLE XLVI

COMPARISON OF ALTERNATIVE OBJECTIVE FUNCTIONS

	Objective Function				
Value of Activity	Minimize Total Cost	Minimize Patient Travel	Minimize Squared Travel	Minimize Variable Cost	Minimize Net Subsidy
Total Cost	76,506,000	76,651,000	77,045,000	76,734,000	77,429,000
Patient Travel	85,099,000	83,497,000	85,454,000	83,510,000	88,915,000
Squared Travel	2,072,684,000	1,994,135,000	1,935,521,000	1,994,461,000	2,148,212,000
Variable Cost	28,700,000	28,581,000	28,875,000	28,578,000	29,360,000
Net Subsidy	4,449,000	4,408,000	4,408,000	4,408,000	4,365,000
Ambulance Emergency Miles	123,000	125,000	125,000	123,000	123,000
Ambulance Transfer Miles	61,000	50,000	50,000	50,000	61,000
Nurses Required in Area	593	608	608	608	592
Physician Miles	683,000	650,000	650,000	664,000	684,000

Specialized care, because costs differences between hospitals are more sizeable and because more travel is required, has more changes in patient flows. Here Oklahoma City is abandoned as a supply point except for a few Watonga residents. Shattuck gains patients from Dewey County, Ponca City gains patients from Noble County and its own county, Kay, and Enid draws new patients from Blaine County.

The resulting changes in hospital patient loads are in: an increase in annual usage of the Okeene hospital from 4,276 to 6,719 patient days; an increase in the Shattuck patient load to 18,535 patient days from 16,596, all the gain being specialized care days; and a decrease in Enid hospital usage of 9,301 patients with a shift in patient composition to a smaller percentage of specialized care patients. The Ponca City hospital has 66,051 patients, up from 54,751 in the minimum cost model, most of the gain being specialized care patients, and Woodward hospital increases its patient days by 996.

The degree to which the two objective functions duplicate hospital usage varies with location. Minimizing patient travel inadequately explains the local populace's avoidance of the Okeene hospital, yet predicts usage better for the Shattuck hospital than minimizing cost. Patient travel does a horrible job estimating usage of the Ponca City hospital, which is also overestimated by cost minimization.

Physicians visits increase sharply in Shattuck from 28,706 to 32,584 with intracounty reshuffling occuring in Kay, Texas and Woodward counties. The number of nurses required increases from 23 to 25 in Blaine County, 32 to 36 in Ellis County, 132 to 153 in Kay County, and 37 to 39 in Woodward County. Most of these increases in nurses represent shifts from Oklahoma City, Amarillo, and a decrease from 233 to 218 in Garfield County.

Minimizing of patient travel reduces ambulance transfer mileage from over 61,000 miles to about 50,000. This is because trips are shorter for many transfers and because transfer from Kay County is no longer required.

Minimizing Gravity Travel Function

An objective function similar to patient travel is the gravity travel function, in which distances are squared making long trips particularly unattractive. This solution varies from the minimum patient travel solution by substitution of two short trips for one longer trip on several instances. All such changes involve facilities at their capacity. For example, Grant County residents, when patient travel is minimized, fill available in the Blackwell hospital, with the remainder going to Enid. When the gravity function is used, all the excess Grant County patients go to Blackwell, with some Blackwell residents bumped from their local hospital to Ponca City, in turn bumping Noble County residents back to Enid. The net effect is always zero.

The objective functions value decreases 2.9 percent from its value when patient travel is minimized and 7.1 percent from its value when cost is minimized (Table XLVI). Patient travel is increased 2.3 percent and cost 0.4 percent from their values when patient travel is minimized.

Minimizing Variable Costs

Both travel distance and cost are included when the variable costs of health care are minimized. A 25 percent coinsurance system is assumed for costs other than travel costs, which are borne entirely. This has the effect of weighting travel costs at four times the rate of other costs. Such a solution will, of course, be a combination of the minimum cost and minimum travel solutions.

Hospital utilization is the same as in the minimum travel solution with two exceptions stemming from one change. Noble County residents switch from Ponca City to Enid for their specialized care. This decreases the usage of the Ponca City hospital by 1,515 patient days, and increases usage of Enid hospitals by the same. Other facility usage remains unchanged from the patient travel solution except for a small adjustment in Ponca City physician visits to Tonkawa.

The value of the objective function, $28,578,000, is 0.4 percent lower than its minimum cost solution value and 0.01 percent lower than its patient travel solution value. Cost is 0.02 percent lower than its patient travel solution value and 0.3 percent higher than its minimum cost solution value. The magnitude of these differences make it apparent that minimizing variable cost is much like minimizing patient travel.

Minimizing Net Subsidy

When the net subsidy for hospitals is minimized, a sharp contrast is seen. This subsidy is 1.9 percent less than its value when cost is minimized. Although the solution is not unique, the solution given has a total cost 1.2 percent higher than the minimum cost solution and total patient mileage 10.2 percent higher than the minimum travel solution. The minimization of cost for local governments as a whole is achieved, therefore, only at a considerable cost to the populace.

Summary of Various Objective Functions

As may be seen in Table XLVI, the different objective functions have only minor impacts on the value of these functions. This reflects the large fixed component in the health expenditures and patient travel. Variations are in usage of certain pivotal facilities; the Shattuck, Enid and Ponca City hospitals in particular. These hospitals have market shares quite sensitive to travel costs, since they serve areas with several alternatives for specialized care. Primary care is more stable, with sensitivity present mainly in counties with two hospitals. Perceived quality differences in such instances are very important in the choice of hospitals, and unfortunately, is the factor most conspicuous by its absence in the model. This is especially important for hospitals like Perry, which have several larger hospitals nearby. Cost minimization explains observed behavior better than the other objective functions, perhaps because it includes the important aspects of the other objective functions but not their weak points. However, these other functions have important prescriptive value. Minimum cost will be used to model future years and evaluate methodological questions in later chapters.

Summary

The model's ability to duplicate observed usage varies with the service and facility. Emergency services, with their small market areas, require more localized population data for reliable estimation of usage than is available. Hospital demand is more easily predicted using available information. The accuracy of physician usage estimation is not measurable since no usage information is published. It may be assumed that, although physician capacity is about 6,500 annual office visits, survival volume is much less. The overall performance of the model seems satisfactory and the potential even greater. Noting these considerations, the model will be used to estimate future usage in Chapter V and to examine certain research issues in Chapter VI.

CHAPTER V

FUTURE HEALTH CARE USAGE

An important task of health planning is estimating future demands for services to better evaluate the need for construction and staffing of proposed facilities. This is a continuing process since existing facilities need replacement and existing personnel retire. A major use of the model is projection of the system for some future period. In this chapter the study area's health care system is modeled, minimizing cost for the objective function, for 1980, 1985, 1990 and 1995. This simulation includes purchase of additional facilities and personnel where shortages exist, as well as replacement of retiring physicians. The process is cumulative, i.e. facilities constructed in one period continue to exist in later periods.

Projected Population and Demand for Services

Populations for each demand point are projected for 1980, 1985, 1990 and 1995 (Table XLVII). These projections show a large population growth for Texas County, moderate growth for Kingfisher County and Woodward County, and smaller growth for Major, Blaine and Garfield Counties. Alfalfa, Beaver, Cimarron, Dewey, Grant and Harper Counties have a small decrease in population, while Woods, Noble, Kay and Ellis Counties remain approximately unchanged.

TABLE XLVII

PROJECTED POPULATION FOR DEMAND LOCATIONS

Location	Year			
	1980	1985	1990	1995
Alfalfa County	6,592	6,402	6,286	6,232
Beaver County	5,721	5,489	5,283	5,101
Blaine County	12,164	12,543	13,036	13,632
Watonga	3,919	4,092	4,299	4,537
Rest of County	8,245	8,451	8,737	9,095
Cimarron County	3,816	3,682	3,560	3,447
Dewey County	5,131	4,950	4,817	4,723
Ellis County	4,920	4,879	4,877	4,913
Garfield County	58,753	60,749	62,962	65,382
Enid	47,266	49,073	15,029	53,133
Rest of County	11,487	11,676	11,933	12,249
Grant County	6,408	6,172	6,002	5,890
Harper County	4,765	4,626	4,514	4,424
Kay County	46,960	46,339	45,926	45,689
Blackwell	8,129	7,983	7,890	7,836
Ponca City	25,271	25,049	24,898	24,814
Tonkawa	3,149	3,101	3,071	3,055
Rest of County	10,411	10,206	10,067	9,984
Kingfisher County	13,882	14,602	15,444	16,397
Kingfisher	4,235	4,403	4,615	4,866
Rest of County	9,647	10,199	10,829	11,531
Major County	7,911	8,209	8,577	9,012
Fairview	3,058	3,182	3,336	3,516
Rest of County	4,853	5,027	5,241	5,496
Noble County	10,129	10,295	10,543	10,859
Perry	5,231	5,394	5,520	5,687
Rest of County	4,808	4,901	5,023	5,172
Texas County	19,479	21,267	23,202	25,297
Guymon	9,218	10,100	11,053	12,082
Rest of County	10,661	11,167	12,149	13,215

TABLE XLVII (Continued)

Location	Year			
	1980	1985	1990	1995
Woods County	11,152	10,835	10,562	10,329
Alva	7,309	7,324	7,153	7,071
Rest of County	3,843	3,601	3,409	3,258
Woodward County	16,936	17,798	18,772	19,857
Woodward	9,674	10,294	10,970	11,699
Rest of County	7,262	7,504	7,802	8,158
Total	234,719	238,837	244,363	251,184

These population projections serve as input data for the demand model. The projected demand for services are presented in Tables XLVIII-LII. Because these demands are based on population composition as well as absolute size the changes in services demanded over time vary from the changes in population. For example, the population of the entire area is estimated to grow 7.0 percent from 1980-95 yet primary hospital bed days demanded are projected to grow only 3.8 percent. These differences for particular counties may be quite important. Ellis County's population is estimated to decrease by 0.1 percent, but demand for primary bed days decreases by 8.5 percent. A change in the reverse direction occurs in Texas County, where population increases by 29.9 percent and primary bed days by 37.3 percent. Such differences occur for other services and other counties.

Supply of Medical Services

In the supply model physician retirement is considered using birth date information available in the professional directors of MD's and DO's (Oklahoma State Medical Association, 1976, and Oklahoma Osteopathic Association, 1976). Having each physician retire in the first year divisible by five after his sixty-fifth birthday, the supply of physicians in each supply location is reduced accordingly. While many physicians continue to practice after this age, it is generally on a reduced basis, and replacement should be considered at this time. Each community, except Ponca City and Enid, is accessed a $20,000 recruiting and inducement charge to replace a physician, with additional physicians available only in integral units. This figure is arbitrarily chosen. While recognizing that larger communities, like Guymon, would experience

TABLE XLVIII

PROJECTED DEMAND FOR PRIMARY HOSPITAL BEDS BY DEMAND AREA

Location	Year 1980	1985	1990	1995
	(Primary Days)			
Alfalfa County	8,982	8,387	7,916	7,611
Beaver County	6,330	6,145	5,914	5,686
Rural Blaine County	10,058	10,034	10,082	10,258
Watonga	4,378	4,430	4,548	4,746
Cimarron County	3,925	3,853	3,761	3,672
Dewey County	6,531	6,165	5,830	5,558
Ellis County	6,297	6,080	5,884	5,764
Rural Garfield County	12,808	12,900	13,070	13,376
Enid	49,068	50,508	52,388	54,847
Grant County	8,543	7,986	7,505	7,144
Harper County	5,386	6,192	5,027	4,900
Rural Kay County	12,176	11,703	11,315	11,062
Blackwell	9,502	9,148	8,878	8,704
Ponca City	27,799	27,457	27,184	27,062
Tonkawa	3,639	3,443	3,314	3,263
Rural Kingfisher County	9,947	10,503	11,153	11,928
Kingfisher	5,011	5,039	5,144	5,337
Rural Major County	5,762	5,903	6,055	6,260
Fairview	3,574	3,619	3,718	3,878
Rural Noble County	5,487	6,903	5,618	5,729
Perry	6,459	6,287	6,239	6,318
Rural Texas County	9,875	10,846	11,935	13,204
Guymon	8,404	9,453	10,603	11,888
Rural Woods County	5,213	4,760	4,346	4,015
Alva	7,379	7,131	7,034	7,054
Rural Woodward County	8,630	8,807	9,025	9,336
Woodward	9,675	10,396	11,178	12,061
Total	260,840	261,720	264,664	270,667

TABLE XLIX

PROJECTED DEMAND FOR SPECIALIZED HOSPITAL CARE
BY DEMAND AREA

Location	Year 1980	1985	1990	1995
	(Patient Days)			
Alfalfa County	2,541	2,371	2,236	2,149
Beaver County	1,788	1,735	1,669	1,605
Rural Blaine County	2,841	2,833	2,846	2,897
Watonga	1,236	1,250	1,284	1,340
Cimarron County	1,107	1,086	1,061	1,036
Dewey County	1,848	1,743	1,648	1,571
Ellis County	1,782	1,720	1,664	1,630
Rural Garfield County	3,609	3,634	3,682	3,769
Enid	13,857	14,265	14,802	15,504
Grant County	2,416	2,267	2,120	2,018
Harper County	1,520	1,466	1,420	1,384
Rural Kay County	3,440	3,306	3,195	3,124
Blackwell	2,689	2,587	2,510	2,460
Ponca City	7,865	7,765	7,688	7,655
Tonkawa	1,027	971	935	921
Rural Kingfisher County	2,800	2,959	3,144	3,365
Kingfisher	1,417	1,424	1,454	1,508
Rural Major County	1,628	1,667	1,710	1,768
Fairview	1,010	1,023	1,051	1,096
Rural Noble County	1,548	1,565	1,585	1,617
Perry	1,826	1,777	1,764	1,786
Rural Texas County	2,777	3,052	3,361	3,722
Guymon	2,365	2,663	2,989	3,354
Rural Woods County	1,475	1,346	1,228	1,135
Alva	2,078	2,008	1,982	1,989
Rural Woodward County	2,437	2,487	2,549	2,637
Woodward	2,732	2,935	3,157	3,407
Total	73,658	73,733	74,733	76,448

TABLE L

PROJECTED DEMAND FOR AMBULANCE CALLS
BY DEMAND AREA

Location	Year			
	1980	1985	1990	1995
Alfalfa County	251	236	222	212
Beaver County	154	155	152	148
Rural Blaine County	268	269	270	274
Watonga	114	115	117	121
Cimarron County	94	95	94	93
Dewey County	173	166	158	151
Ellis County	168	164	160	157
Rural Garfield County	329	334	339	347
Enid	1,205	1,248	1,297	1,361
Grant County	233	221	209	198
Harper County	136	133	130	127
Rural Kay County	314	307	297	290
Blackwell	247	239	232	227
Ponca City	689	690	690	691
Tonkawa	98	92	87	84
Rural Kingfisher County	246	262	279	299
Kingfisher	134	134	136	140
Rural Major County	149	155	160	166
Fairview	95	96	98	101
Rural Noble County	139	144	151	150
Perry	175	169	166	166
Rural Texas County	234	261	289	322
Guymon	191	219	249	284
Rural Woods County	142	132	122	112
Alva	186	177	173	172
Rural Woodward County	224	232	239	247
Woodward	230	251	273	298
Total	6,618	6,695	6,785	6,940

TABLE LI

PROJECTED DEMAND FOR EMERGENCY ROOM CARE
BY DEMAND AREA

Location	Year			
	1980	1985	1990	1995
	(Visits)			
Alfalfa County	992	964	946	938
Beaver County	861	826	795	767
Rural Blaine County	1,240	1,272	1,315	1,369
Watonga	590	616	647	683
Cimarron County	574	554	536	519
Dewey County	772	745	725	711
Ellis County	740	734	734	739
Rural Garfield County	1,729	1,757	1,795	1,843
Enid	7,112	7,384	7,678	7,995
Grant County	964	929	903	886
Harper county	717	696	679	666
Rural Kay County	1,567	1,536	1,515	1,502
Blackwell	1,223	1,201	1,187	1,179
Ponca City	3,803	3,769	3,746	3,734
Tonkawa	474	467	462	460
Rural Kingfisher County	1,452	1,534	1,630	1,735
Kingfisher	638	662	694	732
Rural Major County	730	756	788	827
Fairview	460	479	502	529
Rural Noble County	724	737	756	778
Perry	801	811	830	856
Rural Texas County	1,544	1,681	1,828	1,988
Guymon	1,387	1,520	1,663	1,818
Rural Woods County	578	542	513	490
Alva	1,099	1,088	1,076	1,064
Rural Woodward County	1,092	1,129	1,174	1,228
Woodward	1,456	1,550	1,651	1,760
Total	35,318	35,939	36,768	37,796

TABLE LII

PROJECTED DEMAND FOR PHYSICIAN OFFICE VISITS BY DEMAND AREA

Location	Year 1980	1985	1990	1995
Alfalfa County	23,095	22,328	21,825	21,582
Beaver County	19,652	18,857	18,144	17,511
Rural Blaine County	28,524	29,164	30,065	31,240
Watonga	13,413	13,980	14,666	15,470
Cimarron County	13,002	12,566	12,167	11,786
Dewey County	17,856	17,171	16,655	16,288
Ellis County	17,136	16,929	16,848	16,925
Rural Garfield County	39,386	40,034	40,896	41,990
Enid	161,073	167,135	173,798	181,109
Grant County	22,437	21,513	20,830	20,377
Harper County	16,390	15,897	15,498	15,184
Rural Kay County	35,853	35,097	34,557	34,237
Blackwell	27,994	27,443	27,085	26,874
Ponca City	86,689	85,864	85,293	85,002
Tonkawa	10,830	10,636	10,503	10,446
Rural Kingfisher County	32,824	34,726	36,895	39,317
Kingfisher	14,588	15,112	15,810	16,662
Rural Major County	16,771	17,338	18,041	18,896
Fairview	10,525	10,936	11,441	12,054
Rural Noble County	16,557	16,847	17,249	17,740
Perry	18,378	18,557	18,940	19,505
Rural Texas County	34,758	37,860	41,246	44,954
Guymon	31,071	34,134	37,445	41,034
Rural Woods County	13,472	12,583	11,855	11,289
Alva	24,867	24,562	24,305	24,065
Rural Woodward County	25,116	25,911	26,893	28,090
Woodward	32,836	35,004	37,334	39,870
Total	805,094	818,171	836,284	859,495

less difficulty replacing a physician than would smaller towns, like Beaver, no accommodation is made for this in the model.

Some communities are allowed to choose between the publicly owned clinic strategies discussed in Chapter III. Also, hospitals in counties short of hospital facilities are allowed to expand capacity in integral units, with such expansion reflected in their costs of service.

No measures are taken to include replacement of outdated hospitals, but communities with hospitals that consistently operate at a low utilization rate would not be expected to build as large a replacement facility as their previous hospital. Such a decision could be easily modeled if the replacement year for each hospital was known.

Results

For 1980 additional hospital capacity is made available for Kingfisher, Alva, Fairview, Wakita, and Seiling. Community clinic opportunities are available to Cherokee, Watonga, Newkirk, Alva, and Woodward. Additional physicians are available to most other locations, except small towns such as Covington and Garber. These small towns are at their upper capacity due to lower relative costs rather than indigenous supporting populations, a limitation of the model present because of aggregation of demand areas.

Of the hospital expansion opportunities offered, Kingfisher expands by 25 beds, Alva by 13 beds, Fairview by 18 beds, Wakita by 16 beds, and Seiling by 14 beds. Cherokee, Watonga and Newkirk build the two physician community operated clinic, and Newkirk, Alva and Woodward build the clinic with a physician's assistant. One physician is hired by Blackwell and three by Kingfisher.

In 1985 expansion of hospital capacity is allowed for Cherokee, Perry and Guymon and a community clinic for Wakita. In addition, for 1985 and subsequent years, the cost differences for primary hospital days due to 1975 capacity utilization are halved under the assumption that, over time, economy measures are taken in lightly utilized facilities, raising their costs. These adjustments often occur as outmoded hospitals are replaced with modern facilities.

Cherokee expands by 12 beds, Perry by 17 beds and Guymon by 22 beds. Wakita builds the two physician community operated clinic. Cherokee, Boise City, Covington, Garber, Tonkawa and Fairview recruit one physician each and Canton, Perry and Guymon each recruit two. The expansions in Perry and Cherokee probably are too large, with overestimation of local demand because of deficiencies in the procedure. Evaluation of new facilities should be conducted only after a comparison run for a known year. If the model predicts usage for that community poorly, it should not be used, as is, for feasibility studies.

In 1990, no new facilities are needed, with only replacement of retiring physicians required. Cherokee, Boise City, Blackwell, Kingfisher, Guymon and Mooreland need one physician each, Beaver, Fairview, and Perry, two each, and Woodward, four. No facilities are needed in 1995 either. One new physician is brought to Beaver, Okeene, Buffalo, Alva and Woodward, two to Canton, Enid and Guymon, and three to Ponca City and Blackwell. Since Enid, Shattuck and Ponca City each require specialists, their physician needs are greater than reflected here, but Enid and Ponca City would have little difficulty replacing physicians, particularly compared to the problems a small town like Wakita might have.

Hospitals

Projected use of individual hospital for each of the four future years is given in Table LIII. Those hospitals which expand in early years have mixed results. The Wakita hospital has a level census for 1980 and 1985, then drops sharply in 1990 and 1995. The Cherokee, Guymon, Perry, and Fairview hospitals all could justify more expansion in 1985 in light of the growth in demand occuring later. Expansion of the Alva hospital empties the Waynoka hospital, as does expansion of the Kingfisher hospital to Okarche. The expansion of the Kingfisher, Fairview, Cherokee, and Perry hospitals decreases utilization of Enid's hospitals, which is probably overestimated already with too many specialized care days.

It is evident from the above discussion that hospital expansion decisions are not independent and repercussions of an expansion in one location are felt both locally and in neighboring hospitals. The viability of hospitals in the second largest town in a county is very dependent upon the actions of the board of the largest town's hospital. Aggressive pursuit of quality increases and expansions of market share can bankrupt hospitals in inherently weaker positions.

Ambulance and Emergency Room Use

The utilization of ambulance services given in Table LIV, follows closely population trends for the county. Emergency room usage, shown in Table LV, behaves similarly. Once again for both of these services the distribution of demand within a county is dependent upon the assumption of uniform population distribution in rural areas.

TABLE LIII

PROJECTED ANNUAL PATIENT DAYS FOR AREA HOSPITALS

Hospital	Year 1980	1985	1990	1995
Cherokee	3,777[b]	6,992	6,914[b]	6,914[b]
Beaver	5,814	5,575	5,365	5,180
Okeene	1,368	5,209	5,550	6,279
Watonga	7,734[b]	7,734[b]	7,734[b]	7,734[b]
Boise City	3,777[b]	3,740	3,618	3,601
Seiling	6,531	6,165	5,830	5,558
Shattuck[a]	16,557	16,443	16,342	16,428
Enid-Bass[a]	43,523[b]	43,523[b]	43,523	43,523
Enid-Memorial[a]	0	0	0	0
Enid-St. Mary's[a]	67,455	61,882	67,099	71,043
Wakita	4,550	4,535	3,900	3,460
Buffalo	3,692	3,547	3,423	3,327
Laverne	1,694	1,644	1,605	1,573
Blackwell	16,090[b]	16,090[b]	16,090[b]	15,931
Ponca City[a]	55,786	49,596	45,742	45,056
Kingfisher	15 565[b]	15,792[b]	15,610	15,792[b]
Okarche	1,978	1,179	1,650	1,757
Fairview	9,336	9,406[b]	9,406[b]	9,406[b]
Perry	5,840	10,861	10,573	10,541[b]
Guymon	14,313	20,300	20,912	20,912[b]
Alva	12,007	11,342	10,861	10,573
Waynoka	584	549	519	496
Woodward	13,514	14,270	15,167	16,270
Mooreland	4,792	4,932	5,035	5,126
Oklahoma City[a]	7,342	7,251	7,232	7,316
Wichita[a]	0	0	0	0
Amarillo[a]	10,880	7,484	9,730	12,969

[a]Hospital offering both primary and specialized care.

[b]Constrained solution.

TABLE LIV

PROJECTED AMBULANCE CALLS BY SUPPLY LOCATION

Location	Year 1980	1985	1990	1995
Cherokee	290	198	187	179
Carmen	56	53	50	48
Helena	14	13	12	12
Beaver	168	169	166	162
Okeene	51	51	51	52
Watonga	277	279	281	287
Canton	51	51	51	52
Geary	48	48	48	49
Boise City	106	107	106	105
Seiling	97	94	90	86
Vici	48	48	48	49
Leedey	29	28	27	26
Taloga	19	19	18	17
Gage	89	87	85	83
Shattuck	89	87	85	83
Enid	1,719	1,765	1,818	1,883
Garber	140	141	143	146
Wakita	62	59	56	53
Medford	37	36	34	32
Pond Creek	50	47	45	43
Deer Creek	100	95	90	86
Buffalo	90	88	86	84
Laverne	60	58	57	56
Blackwell	433	421	411	403
Ponca City	963	961	956	954
Tonkawa	168	161	155	151
Kingfisher	331	341	354	372
Hennessey	97	102	108	116
Fairview	273	280	287	296
Perry	352	351	350	354
Hooker	67	73	80	88
Guymon	359	399	444	495
Texhoma	78	85	93	102
Alva	290	277	267	263
Freedom	41	39	36	33
Waynoka	49	46	43	40
Woodward	367	390	414	442
Mooreland	174	179	183	189

TABLE LV

PROJECTED EMERGENCY ROOM UTILIZATION BY SUPPLY LOCATION

Hospital	Year			
	1980	1985	1990	1995
Cherokee	992	964	946	938
Beaver	861	826	795	767
Okeene	310	318	329	397
Watonga	1,520	1,570	1,633	1,654
Boise City	574	554	536	519
Seiling	772	745	725	711
Shattuck	740*	734*	734*	739*
Enid-Bass	0*	0*	0*	0*
Enid-Memorial	0*	0*	0*	0*
Enid-St. Mary's	9,805	10,070	10,376	10,724
Buffalo	466	452	441	433
Laverne	251	244	238	233
Blackwell	2,323	2,282	2,255	2,240
Ponca City	4,742	4,691	4,655	4,635
Kingfisher	1,944	2,022	2,079	2,207
Okarche	145	175	244	206
Fairview	1,190	1,235	1,290	1,356
Perry	1,525	1,549	1,586	1,634
Guymon	2,932	3,200	3,491	3,806
Alva	1,591	1,549	1,512	1,480
Waynoka	87	81	77	74
Woodward	1,893	2,001	2,130	2,288
Mooreland	546	565	578	578
Fort Supply	109	113	117	123

*Indicates alternative solution.

Medical Personnel

The projected number of physician visits are listed in Table LVI. The cost of physician replacement is seen here clearly as locations such as Seiling satisfy their physician demand at Vici rather than recruit a third physician. As hospital capacity increases so does local demand for physician visits, a reflection of their interdependence in the model. This is seen in Guymon, Perry and Cherokee between 1980 and 1985. The reverse situation is seen for Watonga where limited hospital capacity freezes physician visits at 25,780 for all four periods.

The projected number of nurses required by hospitals and doctor's office are shown in Table XVII. The effects of increasing hospital capacity is seen here also, especially in Alfalfa, Noble, and Texas Counties.

The objective function's value for these future projections and the miles of patient travel are listed in Table LVIII. These figures illustrate the importance of Texas County in the cost of health care. Because of their geographic isolation, panhandle residents must travel great distances for health services not available locally. When the Guymon hospital is expanded in 1985, patient mileage for the system drops nearly 18 percent, most of this decrease due to reduced travel for Texas County residents. As the demand exceeds supply in later periods, mileage increases once again. The importance of this decrease in travel is seen in the drop in total health care costs from 1980 to 1985 despite the increased number of patients served.

The modeling of future periods shows the unequal need for additional facilities and personnel. Some locations, especially Guymon with its large projected population increase, require additional

TABLE LVI

PROJECTED PHYSICIAN OFFICE VISITS BY SUPPLY LOCATION

Location	Year			
	1980	1985	1990	1995
Cherokee	12,500	19,500	21,282	21,102
Beaver	19,379	18,583	17,883	17,266
Okeene	4,561	7,154	6,500	8,930
Watonga	25,780	25,780	25,780*	25,780*
Canton	0	10,210	12,000	12,000
Geary	0	0	0	0
Boise City	12,590	12,466	12,059	11,670
Seiling	13,000	13,000	13,000	13,000
Vici	4,856	4,171	3,655	3,288
Shattuck	28,846	28,946	29,170	29,641
Enid	205,582*	204,449*	206,941*	214,086*
Covington	6,000*	6,000*	6,000*	6,000*
Garber	6,000*	6,000	6,000	6,000
Wakita	6,500*	15,117	13,000	11,534
Medford	12,000	6,396	7,830	8,843
Buffalo	10,484	10,178	9,934	9,738
Laverne	5,645	5,480	5,349	5,243
Blackwell	32,500	31,166	31,652	32,500
Ponca City	102,157	86,420	86,345	87,110
Tonkawa	11,694	12,000*	10,503*	10,447
Newkirk	34,420	30,000	30,000	28,611*
Kingfisher	43,743*	45,500	45,500	45,500
Hennessey	12,000	409	2,156	4,622
Okarche	3,266*	3,929*	5,500	5,856
Fairview	26,000	26,000	29,031	30,511
Perry	19,467*	34,848*	35,137*	35,137*
Hooker	12,000	12,000	12,000	12,000
Guymon	35,710	55,666	57,707	57,707
Alva	35,794	34,853	34,028	33,309
Waynoka	1,951	1,829	1,731	1,654
Woodward	42,587	45,027	47,916	51,471
Mooreland	12,290	12,703	13,000	13,000
Fort Supply	2,458	2,541	2,652	2,763
Oklahoma City	14,683	14,502	14,464	14,632
Wichita	0	0	0	0
Amarillo	20,217	14,740	18,686	24,319

*Constrained solution.

TABLE LVII

PROJECTED NUMBER OF NURSES REQUIRED TO STAFF HOSPITALS AND PHYSICIAN'S OFFICES BY COUNTY

County	1980	1985	1990	1995
Alfalfa	7	13	13	13
Beaver	11	11	10	10
Blaine	17	25	25	27
Cimarron	7	7	7	7
Dewey	12	11	11	10
Ellis	32	32	32	32
Garfield	211	203	213	220
Grant	9	10	9	8
Harper	10	10	9	9
Kay	135	123	115	114
Kingfisher	33	31	32	33
Major	17	17	18	18
Noble	11	20	20	20
Texas	27	39	40	39
Woods	23	22	21	21
Woodward	34	36	38	40
Total	633	637	645	661

TABLE LVIII

COST OF HEALTH CARE AND MILES OF PATIENT TRAVEL
FOR PROJECTED SYSTEM

Year	Cost	Miles
1980	$75,175,000	77,591,000
1985	74,321,000	63,677,000
1990	75,703,000	66,708,000
1995	78,023,000	72,323,000

facilities and personnel to satisfy increased need. Other areas, like Beaver County, facing falling demand have difficulty sustaining their present facilities and retaining personnel.

The community run clinics prove to be an attractive method of insuring physician availability, since these clinics can be very profitable given sufficient business. This hypothetical alternative is suitable only in certain situations, certainly fewer than offered in the model. It has the same staffing problems as private clinics in rural areas. For communities like Wakita in the 1985 situation it is ideal. Here the community has a single physician who is nearing retirement and a hospital which will perish without doctors to staff it. By offering a package deal with an established market the attractiveness of the community versus another community without similar incentives is increased.

The value of the model to project future usage and demands and to evaluate facility replacement and expansion decisions is apparent from the examples illustrated in the four projected years. The caveat concerning feasibility studies should be repeated, however. Unless the model does a satisfactory job of duplicating actual behavior for the base year, it should not be used, as is, for investment feasibility studies. Also, these studies are dependent upon several assumptions in the model and changes in these assumptions can affect their outcome. Therefore, the impact of changes in some of these assumptions are measured in the following chapter.

CHAPTER VI

COSTS OF ERROR IN INPUT DATA

The dependence of linear programming upon its underlying assumptions makes error in these assumptions a topic of special interest, particularly given the separation of these assumptions from the final results by time and paper. Unlike econometric methods which are accompanied by the probability of error in estimation in computer output and accordingly in the presentation of the results, linear programming output yields answers, to several decimal places, with no hint that these answers might be much different were a few input coefficients to change. For the purposes of this chapter, five types of errors are investigated, two in population prediction, two in demand coefficients, and one in error in cost of patient travel.

Effect of Errors in Population Projections

Population prediction is mainly an accounting exercise with few opportunities for error. The most sensitive of the underlying parameters is net migration. Because net migration depends on many factors, some relative and some absolute, the likelihood of continuation of present trends has different probability for different locations, and forecasting of future years, rather than a continuation of past behavior as is assumed in Chapter V.

A second common source of error in population predictions is birth rates. In recent years the nation's birth rate has dropped sharply leaving past population predictions too high. For Chapter V, 1970 birth rates are used to predict population. As an alternative, 1974 birth rates are used.

The population predicted for the area for 1985 from Chapter V, with lower birth rates and with no net migration, is shown in Table LIX. The lower birth rates reduce predicted population by 6.5 percent after 15 years for the region as a whole. Individual counties vary slightly but a 6.0-7.0 percent decrease is the usual range. The migration assumption has a more varied effect. For counties which have been losing population, the effect is an increase in the predicted population; and for those which have had net in-migration, the effect is a decrease. Texas County's estimate for 1985 falls 10.6 percent and Beaver County's increases by 22.1 percent over the base projections.

These two population projection changes have different effects on the demand for services. The assumption of no net migration affects each cohort proportionately, thereby affecting the demand for each service by approximately the same amount, a 3.9 percent increase. On the other hand, the assumption of lower birth rates affect the size of only the youngest cohort, having no effect on older cohorts. This means that services utilized most heavily by older persons remain relatively unaffected, e.g., ambulance calls fall by only 1.1 percent while population falls by 6.5 percent. Emergency room visits, for which the demand data is available only on an overall basis, falls by 6.5 percent. Physician visits, which have relatively stable rates for all population, fall by 5.6 percent, while primary and specialized hospital bed days fall by 1.7 and 1.6 percent respectively, indicating the higher hospitalization rates of older people.

TABLE LIX

POPULATION PROJECTIONS FOR 1985 WITH LOW BIRTH RATES AND NO MIGRATION

Location	Base	Lower Birth Rates	No Net Migration
Alfalfa County	6,402	6,049	6,810
Beaver County	5,489	5,157	6,704
Rural Blaine County	8,451	7,949	8,178
Watonga	4,092	3,824	3,960
Total Blaine County	12,453	11,774	12,138
Cimarron County	3,682	3,453	4,530
Dewey County	4,950	4,662	5,634
Ellis County	4,879	4,591	5,104
Rural Garfield County	11,676	10,988	11,852
Enid	49,073	45,605	49,809
Total Garfield County	60,749	56,593	61,661
Grant County	6,172	5,828	6,837
Harper County	4,626	4,341	5,424
Rural Kay County	10,206	9,587	11,524
Blackwell	7,983	7,482	9,015
Ponca City	25,049	23,391	28,279
Tonkawa	3,101	2,894	3,501
Total Kay County	46,339	43,354	52,319
Rural Kingfisher County	10,199	9,559	9,610
Kingfisher	4,403	4,132	4,148
Total Kingfisher County	14,602	13,691	13,758
Rural Major County	5,027	4,735	4,721
Fairview	3,182	2,984	2,989
Total Major County	8,209	7,719	7,710
Rural Noble County	4,901	4,607	4,931
Perry	5,394	5,056	5,427
Total Noble County	10,295	9,663	10,358
Rural Texas County	11,167	10,405	9,978
Guymon	10,100	9,404	9,026
Total Texas County	21,267	19,809	19,004

TABLE LIX (Continued)

Location	Base	Lower Birth Rates	No Net Migration
Rural Woods County	3,601	3,403	4,291
Alva	7,234	6,680	8,605
Total Woods County	10,835	10,083	12,896
Rural Woodward County	7,504	7,059	7,090
Woodward	10,294	9,610	9,730
Total Woodward County	17,798	16,669	16,820
Total	239,017	223,436	247,707

When inserted into the model, these changes can have important affects upon individual facilities. This is apparent by inspection of Table LX, which lists the estimated patient days for the area's hospitals for 1985 using the three population projection methods. Because of the complementary nature of physicians visits and hospital visits a restriction in the model forces hospital days to accompany physician visits. The lowering of the physician visits required in some locations affects hospital usage elsewhere. An example is Cherokee. The decrease in the number of physician visits referred to Enid lowers the number of accompanying primary patient days of hospitalization transferred to Enid. The result is an increase in the usage of the Cherokee hospital increasing the expansion from 12 beds in the base model to 17 beds in the lower birth rate case. The no migration situation changes individual hospital utilization, especially for those hospitals in counties which had been losing population.

The lumpy investment opportunities offered reflect most the effect of the change in assumptions. As mentioned previously, the Cherokee hospital expansion increases from 12 to 17 new beds with both changes in projections methods. The Guymon hospital expansion falls from the 22 beds for the base projections to 20 beds with the lower birth rates and 14 with no net migration. The Perry hospital shows less change, decreasing by a single bed when birth rates are lowered and unchanged when net migration is assumed to be zero. Physician replacement decisions are also affected. When birth rates are lowered, Canton and Perry replace one fewer physician and when no migration is allowed, Beaver and Seiling add one physician more and Guymon one fewer.

TABLE LX

ESTIMATED 1985 HOSPITAL UTILIZATION WITH DIFFERENT POPULATION PROJECTIONS

Location	Base	Lower Birth Rates	No Net Migration
Cherokee	6,992	8,283	8,263
Beaver	5,575	5,834	6,808
Okeene	5,209	4,222	4,788
Watonga	7,734*	7,734*	7,734*
Boise City	3,740	3,507	3,777*
Seiling	6,165	6,083	6,914*
Shattuck	16,423	16,186	17,125
Enid-Bass	43,523*	43,523*	43,523*
Enid-Memorial	0	0	0
Enid-St. Mary's	61,882	57,753	65,171
Wakita	4,535*	4,535*	4,535*
Buffalo	3,547	3,567	,165
Laverne	1,644	1,543	1,928
Blackwell	16,090*	16,090*	16,090*
Ponca City	49,596	49,043	56,785
Kingfisher	15,792*	15,792*	15,125
Okarche	1,179	1,776	976
Fairview	9,406*	9,382	8,941
Perry	10,454	10,274	10,523
Guymon	20,300	19,878	18,144
Alva	11,342	11,155	12,848*
Waynoka	549	519	1,320
Woodward	14,270	13,347	13,482
Mooreland	4,932	5,526	4,757

*Constrained solution.

The conclusion to be reached from this is that birth rates are not especially important in predicting health care demand and facility utilization because the changes, though sizeable, are in the size of healthy portions of the population. Of greater importance is net migration since it affects all age groups, thereby affecting the size of both the healthy and the unhealthy portions of the population, and the quantity of health care demanded more directly. This is unfortunate because it is very difficult to forecast net migration. The health planner must be careful to incorporate all available information to get the best possible predictions of migration and hence population.

Effect of Errors in Utilization Rates

The second group of error sources investigated are in utilization coefficients. Error may be introduced not because the base figures are incorrect but rather because changes in health care practices occur over time and assumption that current practices will continue for future periods may be erroneous. Two types of changes are considered here: a reduction in the average hospital stay by 10 percent, and a switch to great specialization, hence to a larger proportion of total hospital days specialized care days and a smaller proportion primary care days. These changes have support both in past trends and commonly held beliefs about the future.

A decrease in average stay by 10 percent results simply in a reduction in hospital days by 10 percent. The change in primary-specialized care mix is accomplished by increasing the specialized care portion of hospital days by 10 percent for each ailment, the residual being primary days. This increases specialized care days by 10 percent and decreases primary care days by three percent.

The constraints on capacity for some hospitals, and the complementarity between physicians visits and hospitalization cause the changes to be spread unevenly throughout the system. Hospitals supplying both primary and specialized care days are affected differently than other hospitals. These changes, seen in Table LXI, are so important that alternative scenarios merit consideration when estimating usage of facilities for health planning purposes.

The marginal nature of the hospital expansion considered makes expansion particularly vulnerable to the stay reduction, but the change to greater specialization also affects these expansion decisions. The Cherokee addition drops from 12 to 6 beds when stay is reduced and increases by 4 beds to 16 when specialization increases. The Perry expansion falls to 13 from 17 in both instances and the Guymon expansion falls to 15 and 20 from 22 for stay reducation and increased specialization, respectively.

The effect on new facility construction makes the appropriate future changes in utilization rates doubly important, since error in these decisions is especially costly. The changes in stay have greater immediate impact on the primary hospital but the increased specialization is probably more important to the viability of the small rural hospital in the long run.

Effect of Travel Cost Changes

The final possible error studied is a currently popular topic, the effect of doubling travel cost. Its effect is minimal. Total cost increases from \$74,321,000 to \$74,511,000, a 0.26 percent rise,

TABLE LXI

PROJECTED 1985 HOSPITAL UTILIZATION FOR DIFFERENT HOSPITAL DEMAND SCENARIOS

Hospital	Base	Reduced Stay	Increased Specialization
Cherokee	6,992	5,265	8,135
Beaver	5,575	5,018	5,981
Okeene	5,209	3,915	3,915
Watonga	7,734*	7,734*	7,734*
Boise City	3,740	3,366	3,737
Seiling	6,165	5,548	5,980
Shattuck	16,423	14,780	17,274
Enid-Bass	43,523*	43,523*	43,523*
Enid-Memorial	0	0	0
Enid-St. Mary's	61,882	52,063	62,325
Wakita	4,535*	3,360	4,535*
Buffalo	3,547	3,193	3,556
Laverne	1,644	1,480	1,480
Blackwell	16,090*	16,090*	16,090*
Ponca City	49,596	44,276	49,497
Kingfisher	15,792*	13,887	16,792
Okarche	1,179	1,061	1,668
Fairview	9,406*	8,570	9,237
Perry	10,454	9,409	9,409
Guymon	20,300	18,270	19,693
Alva	11,342	10,208	11,041
Waynoka	549	494	494
Woodward	14,270	12,843	12,843
Mooreland	4,932	4,439	5,784

*Constrained solution.

but the change in the solution is minimal. A switch in emergency room destination for some Woodward County residents and Kingfisher residents going to Enid rather than Oklahoma City for their specialized care are the only changes occuring in the solution. Total mileage decreases by only 32,000 miles. The effect is so small because travel costs are already an important determinant of the supply source decision, and where it is not the determining factor in the decision, constraints often prevent it from assuming its usual importance.

Summary

Except for the change in travel cost, all inflation is assumed to be uniform. Should prices of one type of care get far out of line with the others, some substitution will take place. However, consideration of this possibility requires better information regarding trade-offs between alternative types of treatment. This study of the importance of error in specification shows that some times of error are generally unimportant but others are very important since this group is a very heavy demander of health care. Errors in predicting the younger population are less important.

Changes in future usage rates should be considered, especially when new facility feasibility is being evaluated. Travel cost changes are not very important since travel is already near its minimum. A reasonable rule of thumb in determining whether a factor is an important potential source of error is its effect on estimating primary hospital demand. When in doubt, the cost of revising the problem is small enough to justify testing alternative scenarios. Any forecasting has some error included. The goal is to eliminate the large error.

CHAPTER VII

SUMMARY, CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

Objectives and Procedures

The main objective of this research is to develop a procedure which models a rural health care system in a manner consistent with the types of problems confronting regional health planners. This objective was met through three steps. The first was description of the system. This step involved study of the health literature concerning operations of each part of the system and of the system as a whole. Upon this theoretical base was built a framework incorporating those factors considered important in the performance of a health care system. The most important of these factors is proper treatment of the role of the physician in the health decision process. The second step was the development of the data base necessary for its use. Fundamental in this data base was in inventory of supplies and demanders in the study area. In addition, utilization rates, travel mileages, operating budgets for supply facilities, and many interaction coefficients were required to translate the theoretical system's model to the quantitative functional model. The third step was development of the model and testing it in an actual situation for its strengths and weaknesses and to discover the intricacies of its efficient use.

Findings and Conclusions

The model developed has several characteristics considered important by health researchers and planners not combined in any other single model. The most important of these characteristics is joint consideration of several services, with inclusion of interactions between services. The most important of these interactions is the role of physicians in the use of other services. The capability to handle several objective functions is also important. Health planners are directed to evaluate system performance using several criteria, and the ability to use a single model to do so allows comparisons otherwise not possible. Since the model is a spatial equilibrium model, two important factors in rural health care delivery, cost and distance, may be simultaneously considered.

The study area is a rural region representative of the Great Plains. The area has two cities larger than 10,000 people, both in the eastern third of the area, and some counties which are very distant from any populous area. This cross section provides counties similar to a broad range of Great Plains conditions.

A comparison with actual performance of the system in 1975 is made for several objective functions. These functions showed quite similar results, due mainly to the limited number of choices of facilities to rural residents for health care. A minimization of total cost of health services for the study area proved to be most satisfactory, since it includes many of the important characteristics of the other objective functions. Other objective functions considered were minimizing patient travel, minimizing a gravity travel function, minimizing variable costs, and minimizing the net subsidies for the area's hospitals.

The minimum cost objective function was used to estimate future health facility usage. This future usage estimation involved expansion of existing facilities where needed and replacement of retiring physicians where needed. The feasibility of several possible investments was examined. Use of the model for prediction of demand for health services for future years illustrated three points. First, it demonstrated the model's value for estimating future usage of existing facilities, revealing possible shortage and surplus areas. Second, it displayed the model's use in feasibility studies for potential facilities. Third, the projected system gave evidence of the value of the model in choosing between alternative investments. While only a few varieties of investment were used, these examples pointed out the potential for evaluating investments and decisions of many other types.

The study of the cost of certain types of error illustrated the value of conscientiousness in gathering the data and preparing the model. Estimated net migration rates and future trends in demand for services were found to be especially important. Changes in birth rates and travel cost proved to be of lesser importance. The relative costs of nearby facilities is quite important, but absolute levels are less so.

The study overall showed the model can duplicate the performance of a rural health care system and can be used to evaluate investment decisions and other health planning issues. Alternative scenarios can be compared if the user desires. Care must be taken in specifying certain input parameters, since some services are quite sensitive to small changes.

Policy Implications

This model for a health system is potentially very valuable. A health planner skilled in using this tool could address many problems arising regularly in an objective manner, using fewer man hours than required to get the same information using other methods. Of special importance is the capability for evaluating proposed facilities. With the potential for generating future usage patterns based on population mix, the impact of the proposed facility on both local and neighboring populations and facilities may be measured using several objective functions. Alternative scenarios may be compared to study the cost of unforeseen change. Treatment as a system is important since interaction occurs between neighboring facilities, neighboring communities, and between different services.

Future changes in health technology and length of patient hospitalization have important implications for the rural hospital. As specialization increases and as average stay decreases, the patient loads for the small primary care hospital decrease. The survival of such a hospital depends upon recognition of this changing environment and the appropriate response to its changing status in the health care system. If, as some suggest, the small rural hospital is destined to be merely the entry point into the health care system rather than a major supplier of a final product, then the type and number of ancillary services offered by such hospitals needs careful examination.

Limitations of the Study

Several limitations of the study are apparent. The first is the indirect method of including quality differences in hospitals. The method used attaches only one cause to observed behavior when several items may be responsible.

This limitation is only one of a larger group, those limitations resulting from inadequate or improper data. This deficiency could be remedied partially by the health planner who has better access to information sources. However, much of the data needs require a series of studies into the productivity and economics of hospitals, clinics, and other services of the type done previously in the farm management area. Many of the same techniques are applicable; only their implementation remains.

The lumping of secondary and tertiary care into specialized care forms a conglomeration which detracts heavily from the accuracy in modeling specialized care. It is amazing that no effort has been made to distinguish between the two services given their suggested importance in the health literature.

Physician productivity is a major determinant of health care demand and this model's dependence on rather casual estimates of production coefficients is a serious limitation. This area, dealt with in just a few sources, is an important area for future research with benefits for widely diverse areas, including studies such as this.

The final limitation noted is the aggregation of the system into only five services. While even these five required extension beyond the scope of the data, much more useful estimates could be obtained were all ailments not grouped together into the large groups of primary and specialized care days. Being able to separate these patient days into demands for ancillary services and support personnel would be a giant step forward. While such research would involve considerable expense and time gathering primary data, the returns in terms of better planning information would justify it.

The most valuable future research potential in this area is probably in alleviating the above limitations. Physician productivity is a particularly attractive area. Further study of hospital costs seen in order. These studies should concentrate on costs of services so these costs are consistent with demand data. Probabilistic studies of facility usage are interesting, but of limited value for rural areas because of the limited number of choices. Health care is a potentially interesting area for application of many of the research tools used in other areas of economics, with only imagination and data imposing restrictions.

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