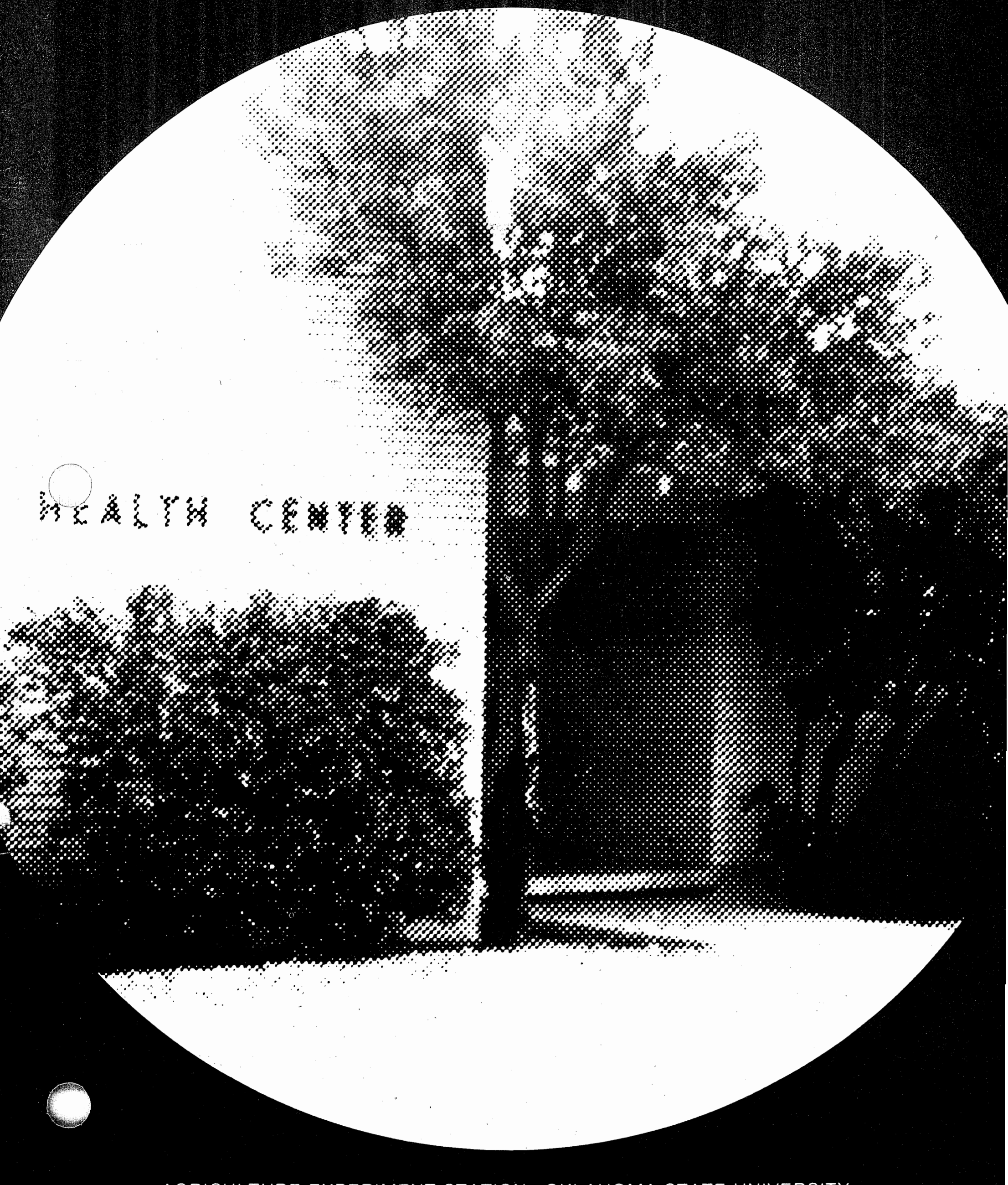
A MODEL ANALYSIS OF RURAL HEALTH CARE SYSTEMS



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A Model For Analysis Of Rural Health Care Systems

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CHAPTER I

Introduction

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 which includes 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 else where. The total model is valuable because it combines many of the factors important in a regional health care system into a single analysis.

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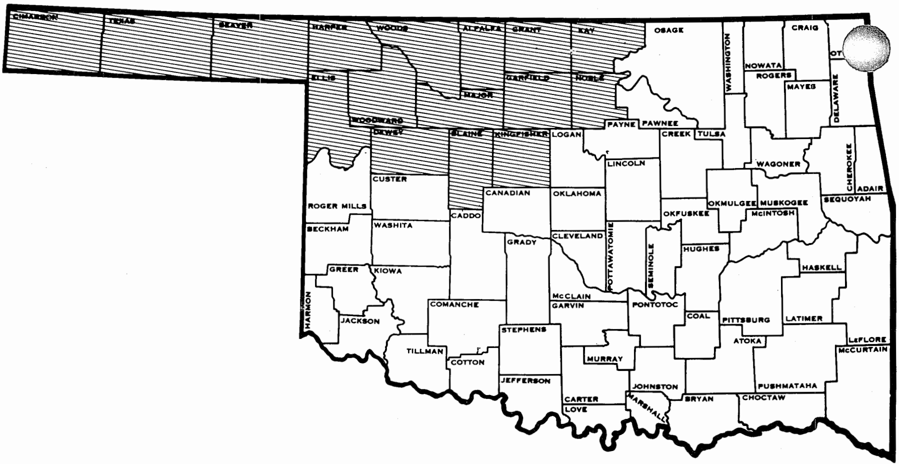

Figure 1. Map of Oklahoma Showing the Area of the Study

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.

CHAPTER II

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 legislated directives for 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 program for low cost while incorporating 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 limitations 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 the objective and all relevant constraints. 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 using mixed integer programming to overcome difficulties with 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

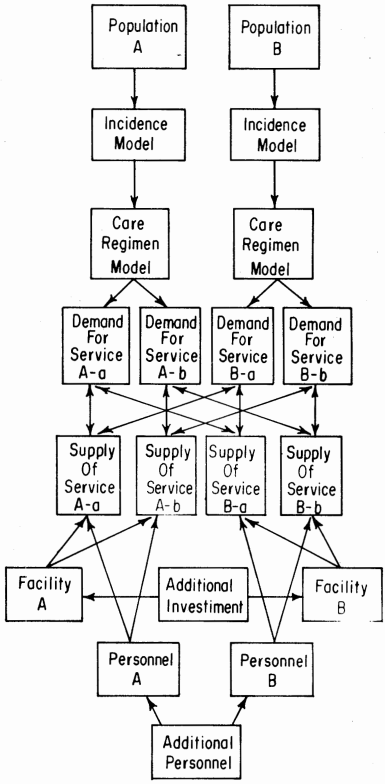

Figure 2. System Relationships for the Two Location, Two Service Model

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.

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 each sex, hence 22 cohorts in all.

Population Projections. Future population determines future demand and as such, its accurate estimation is fundamental to successful estimation of usuage 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 of 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 sex 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 sex 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 requirements of the model is not available so national data are 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 a net 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 1. 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.

Table 1. 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).

Incidence Model

Hospitalization rates for 18 classes of ailments for Oklahoma are taken from May, Doeksen, and Green (1978), 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 2, the expected stays in Table 3, and the expected hospital utilization, in days per year, per 1,000 people in that cohort are found in Table 4.

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 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 hospitalization patterns are 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.

Table 2. Incidence Rate 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+
	(cases per 1000 population)							
Infective and Parasitic	3.000	3.800	3.400	6.800	2.400	7.100	5.100	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	138.500
Tonsillectomy	8.600	1.900	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 (1978)

Table 3. 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	8.800	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	4.500	6.200	7.100	8.400	5.900	6.700	8.000	7.900
Congential 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 (1978)

Table 4. Average Annual Hospital Usage 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	11.100	16.720	18.740	27.200	9.360	31.950	25.500	116.050
Neoplasms	3.080	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	16.550
Mental Disorders	6.240	42.000	50.050	163.080	2.540	79.920	84.360	154.000
Nervous System and Sense Organs	13.500	17.980	42.640	73.670	8.400	23.460	47.040	144.000
Circulatory System	2.000	35.990	353.220	1362.240	1.410	58.460	245.650	1244.700
Tonsillectomy	13.760	4.940	0.500	0.0	15.040	13.250	0.680	3.000
Respiratory System	37.440	54.530	159.000	647.250	27.750	84.480	183.580	718.110
Digestive System	14.620	56.200	169.320	447.320	9.200	108.630	220.580	723.350
Genitourinary System	6.500	30.450	98.820	365.180	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	11.640	31.980	2.320	10.140	20.460	69.307
Musculoskeletal System and Connective Tissue	3.440	47.120	93.010	172.200	4.720	60.300	157.600	425.020
Congenital Anomolies	10.290	3.920	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	147.400	0.0	0.0	0.0
Symptoms and Ill-Defined Conditions	9.280	22.140	62.640	155.400	8.640	56.160	87.000	312.420
Accidents, Poisoning and Violence	24.180	65.720	83.200	213.720	17.200	79.380	117.780	426.300

Source: May, Doeksen, and Green (1978)

Table 5. 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).

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 5. For example, if a county had 400 residents less than 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 6.

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 (1978). 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.

Physical 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 7.

ble 6. 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

Table 7. 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.

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 spital, 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 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 physical 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 8.

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 9.

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 is based on the experience 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 8. 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 9. 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 chosen 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 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.

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 cost differences reflecting different service offerings be adjusted to extract 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 beds, 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 certain relevant financial statistics are computed from the annual operating budgets. 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.

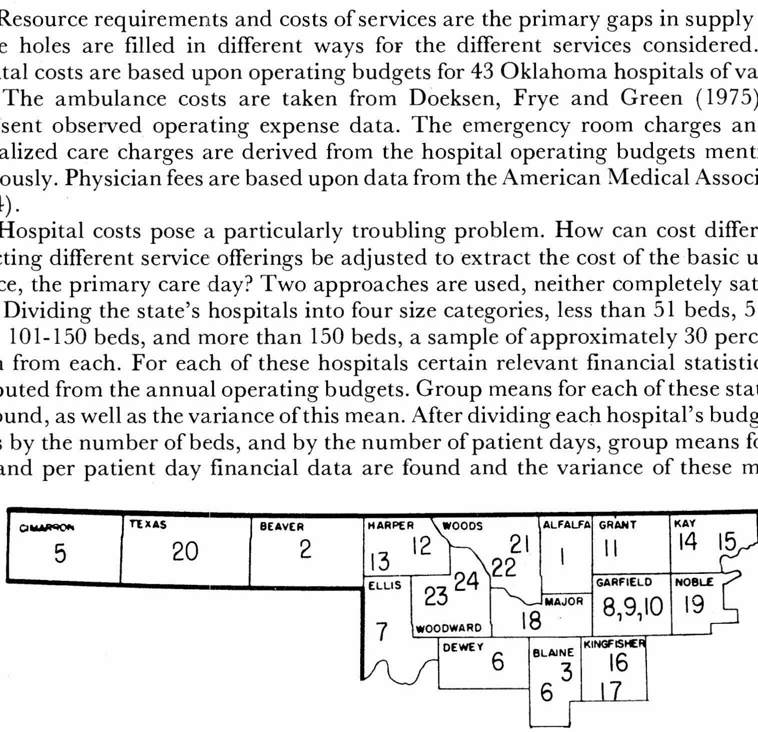

Figure 3. Map showing Location of Hospitals in Study Area

LEGEND

1. Cherokee
2. Beaver
3. Okeene
4. Watonga
5. Boise City
6. Seiling
7. Shattuck
8. Enid - Bass
9. Enid - Memorial
10. Enid - St. Mary's
11. Wakita
12. Buffalo
13. Laverne
14. Blackwell
15. Ponca City
16. Kingfisher
17. Okarche
18. Fairview
19. Perry
20. Guymon
21. Alva
22. Waynoka
23. Woodward
24. Mooreland

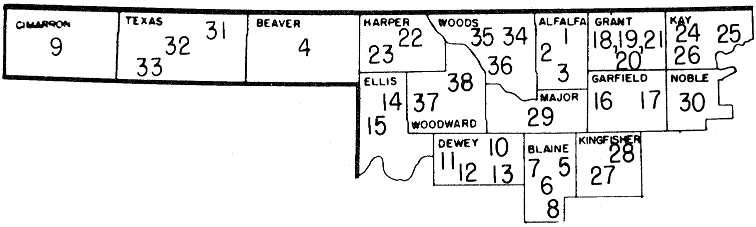

Figure 4. Map Showing the Location of Ambulance Services in the Study Area

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

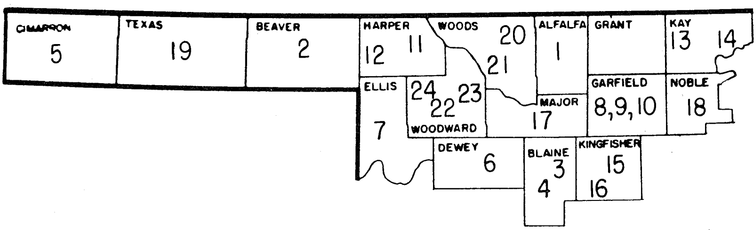

Figure 5. Map Showing the Location of Emergency Rooms in the Study Area

LEGEND

1. Cherokee
2. Beaver
3. Okeene
4. Watonga
5. Boise City
6. Seiling
7. Shattuck
8. Enid - Bass
9. Enid - Memorial
10. Enid - St. Mary's
11. Buffalo
12. Laverne
13. Blackwell
14. Ponca City
15. Kingfisher
16. Okarche
17. Fairview
18. Perry
19. Guymon
20. Alva
21. Waynoka
22. Woodward
23. Mooreland
24. Fort Supply

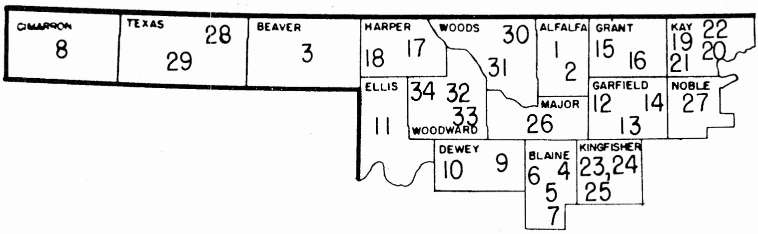

Figure 6. Map Showing the Location of Doctors in the Study Area

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

Selected portions of this information for the small hospitals, i.e., those of 50 beds or less is presented in Tables 10, 11, and 12, based on a sample of 22 hospitals of a total population of 65. Table 10 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 are from inpatient activities, and a profit margin of 2.5 percent is shown.

Taking per bed figures, seen in Table 11, is somewhat meaningful, since there is a substantial size range 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 12. When this is done, 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 should, because non-collectable revenues are included in the total revenue figure.

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 13-15. 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 of 58-99 beds and 135-284 days of occupancy per ye

Table 10. 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 11. 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 12. 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

Table 13. 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 14. Selected Financial Operating Figures Per Bed for a Sample 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 15. 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

The profitability spread ranges from a $4,000 loss to a $180,000 profit.

As with the small hospitals, the coefficient of variation for total expenses decreases with 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 16-18 show the financial operating information for the 101-105 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, so outpatient revenue comprises 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. This 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 $4,500, 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 $2,600 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 raw totals are considered.

The financial information for hospitals larger than 150 beds is in Tables 19-21. From a population of 24 hospitals, seven are sampled, or 29.2 percent. These have an average size of 368 beds and an average 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 really unprofitable sample hospital, losing $296,000, and only one hospital with an occupancy rate of less than 240 days per year.

Table 16. 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 17. Selected Financial Operating 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 18. 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 19. 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 20. Selected Financial Operating Figures Per Bed for a Sample 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 21. 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

From this summary data it appears that two distinct groups exist. The group of smaller hospitals has non-salary expenses per bed of approximately $8,000 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 of greater importance in cost differences.

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]

$$EXPP = 25.72 + 2.833\ SER + 11664\ BEDS/PD$$
$$(2.22) \quad (6.85) \quad (5.29)$$
$$R^2 = 0.726 \qquad D.W. = 1.77$$

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 Commission (1976b). The expenses per patient day are from the hospital budget study mentioned previously.

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 utilizing information from the Oklahoma Blue Cross, given in Table 22, in conjunction with the information in Table 8. 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.

[1]Value in parentheses is the t statistic.

Table 22. 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).

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 for sample hospitals with less than 100 beds, into the estimated equation, yielding an expected cost for one day of primary care of $92.44. Therefore, since 35.3 percent of all neoplasm cases are primary cases and cost $92.44 per day for 7.18 days. Then, $234.29 of the $1,101.23 average neoplasm bill is spent for primary days, the remaining $779.94 being specialized days. Dividing this by the average stay and the weight, 0.647, an average cost per specialized day for neoplasms of $167.46 is found. An identical procedure is used for the other eight categories with 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 (2.1), with 4.31 services assumed to simulate a homogeneous product. The cost per primary day derived thus is found in Table 23.

The cost of specialized hospital care is dependent upon occupancy, as is the cost of primary 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 24.

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 charges for hospitals because only one choice is usually available.

Physician charges vary with community size. The rate structure shown in Table 25 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

Table 23. 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	111.4[illegible]
Northwest Community Hospital	98.9[illegible]
Oklahoma City Hospitals*	88.00
Wichita Hospitals*	88.00
Amarillo Hospitals*	88.00

*Hospitals for which costs are estimated synthetically.

Table 24. 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

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 Association, 1976, p. 112). These figures are then adjusted from occupancy differences and group means for the four size classes are derived. These charges, shown in Table 26, 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 is made to extract them, thereby introducing the assumption that 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.

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

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

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

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

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 size, this distinction is weakened by recognition that average daily census is related to the subset of the

[2] Value in parentheses is t statistic.

Table 25. 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).

Table 26. 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

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 a 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 27. A limitation on the distribution of this capacity between primary and specialized days of a minimum of 60 percent primary days is 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 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.

Table 27. 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

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 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.

Ambulance Capacity. 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 some probability of 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 queuing theory. 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 28 is compiled.

The Ehrland equations (Saaty, 1961, pp. 38-44) show 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

$$L = \frac{p}{1-p} = \frac{v}{u-v}.$$

Using Table 18 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 having all the ambulances in use when one is required, i.e., 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 28. 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 (2.2) 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 is 3.16 calls per day, or 1,155 calls per year.

Table 28. Mean of the Poisson Distributions Associated with Queues of Various Lengths or Greater for Selected Probabilities of Such Lengths

	Queue Length			
Probability	**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

Doeksen, Frye and Green (1975, pp. 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, pp. 4-5) indicate that it represents 5.97 percent of the week's ambulance demand, so an annual rate of 693 calls is implied if 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

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

is obtained. This method assumes that the probability of a queue of two or more during the higher demand portions of the week which exceeds 0.0025 is offset by the probabilities lower 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 29, 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.

Table 29. 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).

New Facilities

In shortage areas, purchase of new facilities may be required. For this reason, initial costs for certain facilities are necessary. The types of facilities considered are additional hospital capacity, new clinics, and ambulance service.

Hanson, Doeksen, and Green (1978) 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 per bed in four Oklahoma expansions of 20-40 beds 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 30. 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 31. Table 32 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 as much as 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 sufficient variety to offer reasonable choice. These budgets are a composite of information from different sources.

Doeksen, Stackler, Dunn, and Sheets (1978) present a budgeting procedure by which the costs of a community clinic may be estimated. The procedure is general, allowing several options for financing, operating 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.

Table 30. 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

The budgets are calculated using Doeksen, Stackler, Dunn, and Sheets (1978), 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 33. It is assumed that financing is arranged jointly through 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 34.

Table 31. 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 32. 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

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 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 35.

Table 33. 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 5½% for 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)

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 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 36. 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, a rough approximation based only on experience must often 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.

Table 34. 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 5½%		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 Nurse	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
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

Table 35. 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 5½%		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
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 36. Example Operating Cost Budget for a Rural Ambulance Service

Category		Amou[illegible]
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 Radio	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	42[illegible]
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 Sector

The interaction model combines the demand sector with the supply sector in the manner which minimizes the objective function. This 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 0 in 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 0 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 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.

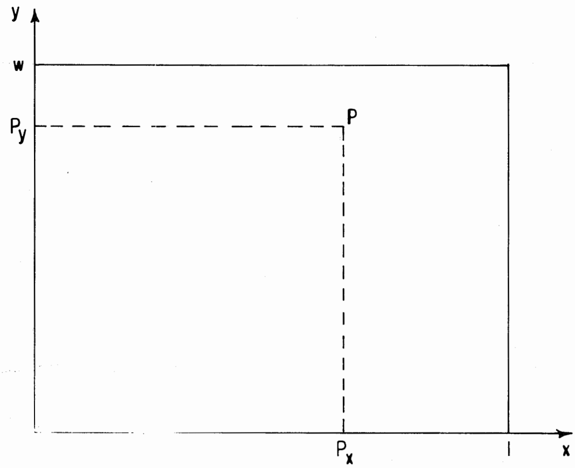

Figure 7. Travel Distance Illustration

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 offices 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 37.

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.

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.

Table 37. 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

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 supportable from some perspective of the health facility choice.

While these objective functions will be evaluated for their descriptive ability, they may be used to evaluate the system's efficiency in a perscriptive 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, so an assumption of no insurance provision detracts little from the solution.

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, assuming 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. T 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 with each other and with 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.

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

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

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 III

MODELING THE PRESENT SITUATION

The reliability of a model's estimates are best measured by comparison with a known situation. Such an opportunity is available through modeling the area health care system for 1975 since 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 II 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 38. 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 five percent of the official estimate. The aggregate totals are different by only 0.47 percent. The estimates need not be identical 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 39. Additional facility demands not in Table 39 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 interhospital 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 40. 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. Because Memorial Hospital's low occupation rate

Table 38. Population Predictions from the Population Model Compared w 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
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.

Table 39. Demand for Various Health Services by Demand Area

Location	Hospital Beds	Ambulance	Emergency Room	Physicians	Specialized Care
Alfalfa	9667.61719	264.279320	1032.67353	24174.5117	2737.59985
Beaver	6384.50000	149.249341	899.808105	20470.6172	1804.25806
Blaine	10102.1680	263.396484	1222.56618	28169.1405	2854.89966
Cimarron	3970.35669	93.51248	596.762451	13485.0664	1419.39453
Dewey	6646.47656	175.496902	807.269775	18679.3789	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	208.951324	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	6923.38672	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 (city)	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	18381.0000	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	260487.315	6482.98828	34920.9609	796659.750	73596.0625

Table 40. 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
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.

makes its cost per patient day higher than the two other Enid hospitals, it is excluded entirely from the solution. A more minute delineation of the county and the relationships of the physicians to specific hospitals might yield a more realistic solution. For the three Enid hospitals combined, the estimated utilization is somewhat higher than the actual utilization, 123,575 and 113,881, respectively.

Counties with accurate 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.

In addition to Garfield, counties with overestimation of usage are Alfalfa, Cimarron, Noble, Kay, and Texas. Alfalfa and Cimarron Counties lower actual utilization undoubtedly reflects an overestimation of the number of hospitalized patients two physicians can handle. The Noble County estimate with Ponca City, Enid, and Stillwater all in adjacent counties, reflects quality differences not reflected in costs. Sizeable overestimation of total number of patient days is the apparent reason for the difference between actual and estimated utilization for Texas County. 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 regation of all specialized care days. These hospitals do not actually satisfy all specialized care needs and many of those patients routed to Enid and Ponca City could not be treated there satisfactorily.

A more perplexing problem is the large estimated under utilization 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 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 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. Because the choices offered are based on observed behavior, these movements are similar to those illustrated in the Patient Origin Study, except most multiple destination movements are replaced by single destination movements.

Ambulance Usage

The demand for ambulances from individual facilities is given in Table 41. The capacity problem never arises at the probability of 0.0025, so the 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, with this figure approached only in the larger cities. The ambulance decision process is more dependent upon ponse time than cost, so capacity over-utilization is not a problem in rural areas.

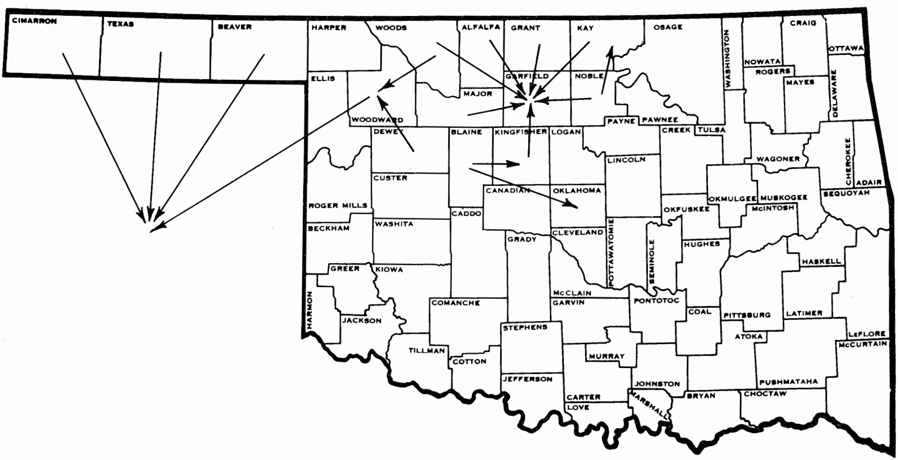

Figure 8. Out of County Movements for Primary Hospital Care

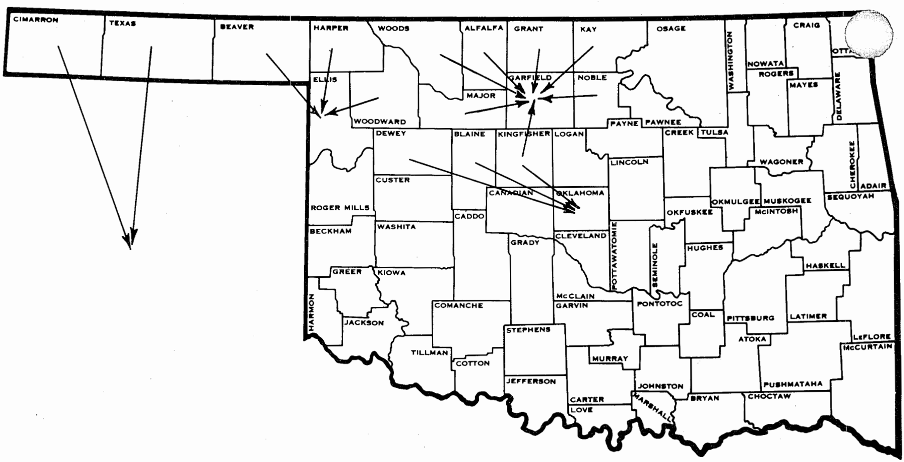

Figure 9. Out of County Movements for Specialized Hospital Care

With few exceptions, rural counties have areas inadequately served by ambulance service using a response time criterion but 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 local decision maker using the aggregate county demand given in Table 39 and proportion of the county's population in each ambulance service area. This method involves an assumption of uniform composition of the population in all areas of the county. This assumption may be better than the assumption of uniform distribution used 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 possible. The utilization of the emergency rooms in the regions is given in Table 42. Once again, for rural counties with two hospitals, the distribution of demand between facilities is very dependent upon the uniformly distributed population assumption.

Physician Usage

The estimates for utilization of physicians, found in Table 43, indicate that substantial excess physician capacity exists in the area. 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

le 41. 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

(1973), Radtke and Nordblom (1975a), 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 the specialist rich areas of Oklahoma City and Tulsa, average capacity utilization is low. The size of a physician's income is large enough so, 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 ˥ Grant Counties have high utilization, i.e., over 80 percent. Blaine, Dewey, Harper,

Table 42. 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.

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 44 is formed. A Pearson's 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 0.027. This implies 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 patients. 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 cost to the patient of $28,700,000 is derived for 1975. The hospitals netted a $4,449,000 loss. Patie

ble 43. 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*
gfisher	28,550*
nnessey	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.

Table 44. Distribution of Physician Capacity Utilization by Category of County's Largest Community

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

traveled 85,099,000 miles to receive their medical service and physicians trav[illegible] 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 45.

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 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 46.

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 46), a 0.3 percent incre[illegible] In most instances hospital usage is unchanged from the minimum cost solution, w[illegible] exceptions occurring 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.

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 result of these changes on hospital patient loads are: 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, with most of the gain being specialized care patients, and Woodward Hospital increases its patient days by 996 over the minimum cost solution.

The degree to which the two objective functions replicate 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.

ble 45. 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

Physicians visits increase sharply in Shattuck, from 28,706 to 32,584, and intra-county reshuffling occurs 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, 132 153 in Kay County, and 37 to 39 in Woodward County. These increased numbers of rses represent shifts from Oklahoma City, Amarillo, and a decrease from 233 to 218 in Garfield County.

Minimizing 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 space 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 function's 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 46). 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 minimized. A 25 percent coinsurance system is assumed for costs other than travel

Table 46. 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

ts, which are borne entirely. This has the effect of weighting travel costs at four times the rate of other costs. Such a solution is, of course, 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. 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 46, 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 iminimization 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 replicate 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 IV and to examine certain research issues in Chapter V.

CHAPTER IV

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 present 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 47). 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.

These population projections serve as input data for the demand model. The projected demand for services are presented in Tables 47-52. Because these demands are based on population composition as well as absolute size the changes in services demanded over time differ 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 8.5 percent. A change in the reverse direction occurs in Texas County, where population increases of 29.9 percent are estimated primary bed days increases 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 directories of MD's and DO's (Oklahoma State Medical Association, 1976, and Oklahoma Osteopathic Association, 1976). Assuming each physician retires in the first year divisible by five after his sixty-fifth birthday, the supply of physicians in each supply location is reduced by attrition. 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 less difficulty replacing a physician than would a smaller town, such as Beaver, no accommodation is made for this in the model.

Table 47. 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
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

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.

Table 48. 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	6,31[illegible]
Rural Texas County	9,875	10,846	11,935	13,204
Guymon	8,404	9,453	60,603	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

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 caused by 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

Table 49. 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

halved under the assumption that, over time, economy measures are taken in lightly utilized facilities and expansion occurs in heavily used facilities, causing their costs to converge. 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 built 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, reflecting 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 new facilities are needed in 1995. One new physician is brought to Beaker, 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

Table 50. 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

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 hospitals for each of the four future years is given in Table 53. 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 greater expansion in 1985 in light of the growth in demand occuring later. Expansion of the Alva Hospital empties the Wayonka Hospital, as the expansion of the Kingfisher Hospital does to Okarche. The expansion of the Kingfisher, Fairview, Cherokee, and Perry Hospitals decreases utilization of Enid's Hospitals, which may be overestimated anyway 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 hospit

Table 51. 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

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 54, follows closely population trends for the county. Emergency room usage, shown in Table 55, 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.

Medical Personnel

The projected number of physician visits are listed in Table 56. 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

Table 52. 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

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 offices are shown in Table 57. The effects of increasing hospital capacity are 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 58. 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 facilities and personnel to satisfy increased need. Other

Table 53. 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	67,009	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.

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 where compared to 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

Table 54. 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

in these assumptions may affect their outcome. Therefore, the impact of changes in some of these assumptions are measured in the following chapter.

Table 55. Projected Emergency Room Utilization by Supply Location

Hospital	1980	1985	1990	1995
	Year			
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.

Table 56. Projected Physician Office Visits by Supply Location

Location	1980	1985	1990	1995
	Year			
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 57. 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 58. 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

CHAPTER V

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 probabilities for different locations. To estimate the model's sensitivity to such error, an assumption of no net migration will be used for forecasting of future years, rather than a continuation of past behavior as is assumed in Chapter IV.

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 IV, 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 IV, with lower birth rates, and with no net migration, is shown in Table 59. 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 counties which have had net inmigration, the effect is a decrease. Texas County's estimated population 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 affects 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, fall by 6.5 percent. Physician visits, which have relatively stable rates for all population cohorts, 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.

When inserted into the model, these changes can have important affects upon individual facilities. This is apparent by inspection of Table 60, which lists the estimated patient days for the area's hospitals for 1985 using the three population

Table 59. 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
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

projected 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 hospitals in counties which had been losing population.

Table 60. 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 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 method. The Buymon 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 net migration is allowed, Beaver and Seiling add one additional physician and Guymon one fewer.

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 forecase 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 greater specialization, hence to a larger proportion of total hospital days being 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 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 increase 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 61, are so important that alternative scenarios merit consideration when estimating usage of facilities for health planning purposes.

Table 61. 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	61,822	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.

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 reduction 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, but the change in the solution is minor. 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 potential importance.

Summary

Except for the change in travel cost, all inflation is assumed to be uniform. Should prices of one type of care change disproportionately from 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. Accurate estimation of the size of the older population is essential 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 was 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. First a framework incorporating those factors considered important in the performance of a health care system was built. 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 an inventory of suppliers 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 small primary care hospitals 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 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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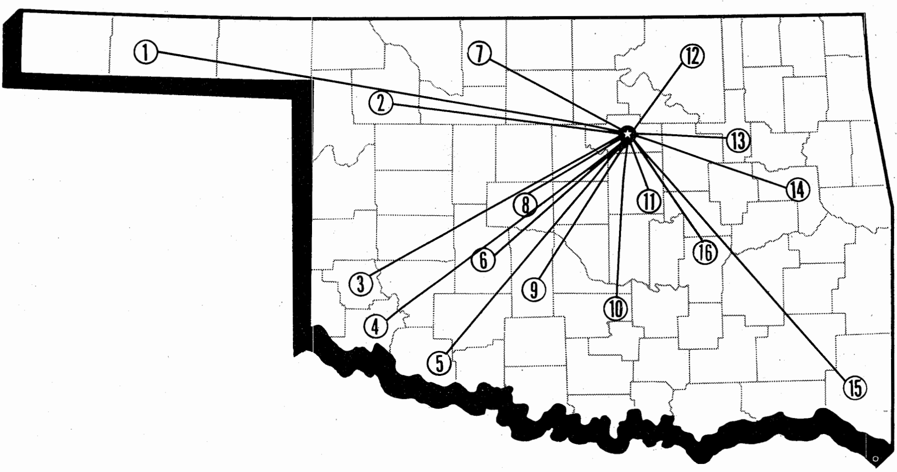
OKLAHOMA

Agricultural Experiment Station

System Covers the State



Main Station — *Stillwater, Perkins and Lake Carl Blackwell*

1. **Panhandle Research Station — *Goodwell***
2. **Southern Great Plains Field Station — *Woodward***
3. **Sandyland Research Station — *Mangum***
4. **Irrigation Research Station — *Altus***
5. **Southwest Agronomy Research Station — *Tipton***
6. **Caddo Research Station — *Ft. Cobb***
7. **North Central Research Station — *Lahoma***
8. **Southwestern Livestock and Forage Research Station — *El Reno***
9. **South Central Research Station — *Chickasha***
10. **Agronomy Research Station — *Stratford***
11. **Pecan Research Station — *Sparks***
12. **Veterinary Research Station — *Pawhuska***
13. **Vegetable Research Station — *Bixby***
14. **Eastern Research Station — *Haskell***
15. **Kiamichi Field Station — *Idabel***
16. **Sarkeys Research and Demonstration Project — *Lamar***