AREAWIDE PLANNING FOR OPTIMUM LOCATION OF HOSPITAL FACILITIES FOR RURAL PEOPLE

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The agricultural economic literature is abundant with least-cost location studies of agricultural processing industries. Yet very little effort has been directed toward similar planning for public facilities in rural areas. The purpose of this paper is to present a conceptual model and its application to the planning of locations for additional multiple service hospital facilities in a predominantly rural area for 1980. The approach is based on the premise that areawide planning, as opposed to substantial reliance upon market mechanisms, is required to allocate health care resources among communities. In this approach it is assumed that all health care service cost functions are long run and that the time period of adjustment is such that fixed capital goods do not restrict adjustments in the service output of hospital facilities.

THE MINIMUM TOTAL ACCESS COST MODEL

The areawide planning problem may be divided into two parts: (1) the demand for health care services in a given area, and (2) the distribution of the facilities and personnel that will most efficiently provide the care to be utilized [1].

Given knowledge of the level of demand or health care needs in a region, the problem is one of determining the number, sizes and locations of various types of multiple service hospital facilities that will minimize the combined cost of patient travel and health service output, i.e., total regional access cost. If we assume there are both economies and diseconomies to size in the production of health services in hospitals, it might be generalized that over the usual range of operation, average health service production cost first decreases at a decreasing rate and then increases as output is increased.[1]

In addition to health service production costs, recipients must bear any travel costs associated with obtaining the health service. Average travel cost per patient depends upon several factors such as the existing geographic distribution of health facilities, the distribution and characteristics of the population, and the configuration of travel routes. In general, however, if the sizes of hospitals were increased (with constant utilization rates), their geographic service areas would expand, and, consequently, average travel cost would rise.

These relationships are presented graphically in Figure 1. Line AA represents the relationship between average travel cost and hospital size, and line BB represents average cost per patient day incurred by the hospital as the size of the institution increases. Since these two costs must be borne by recipients, it is the sum of these costs that is relevant. If these costs do not depend upon one another in any way, it is permissable to add these curves vertically in Figure 1 to obtain line CC which represents average total access cost as a function of hospital size.

Williamson [11] has shown that if we assume uniformity of terrain, uniformity and continuity in transportation facilities, and constant over-the-road costs per patient mile of travel, the size of hospital facility that results in minimum total access cost will increase or decrease as patient population density increases or decreases. Thus, there is a positive relationship between density of population in an area and the optimum size of hospital facility. This relationship can be taken into account in estimating patient travel cost functions for an area.

From the foregoing discussion, it is evident that both the cost of producing services in a hospital and the cost of patient travel affect the optimum size

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[1] Empirical evidence exists from numerous studies to indicate that unit output costs initially decline and then rise as the size of hospitals is increased. For examples, see [1, 2, 3].

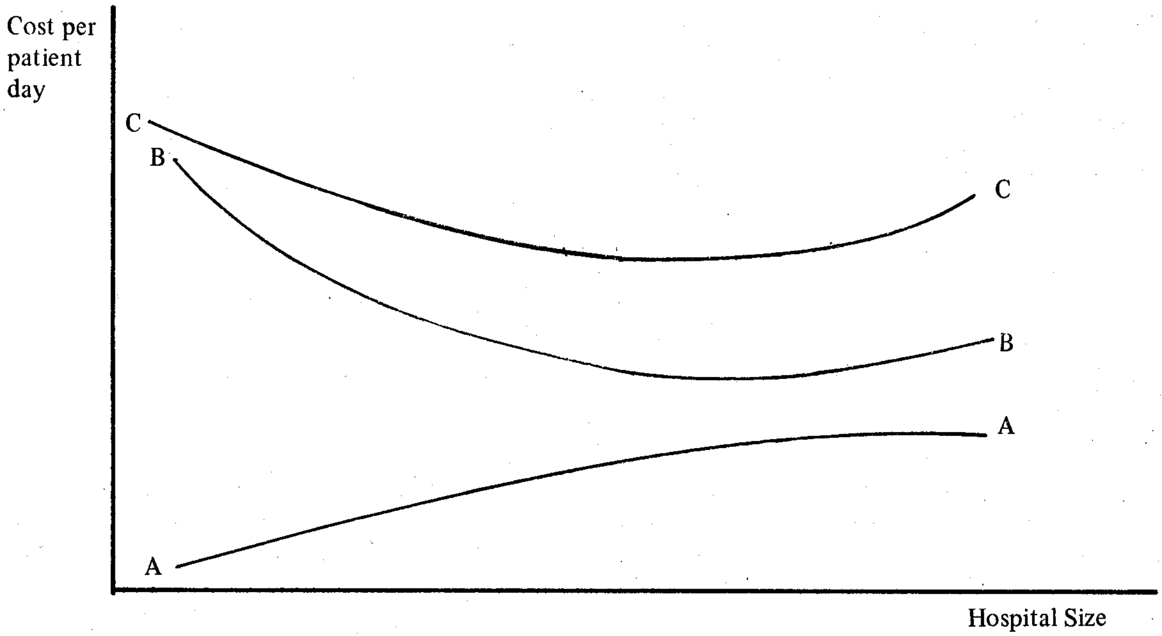

FIGURE 1. PRODUCTION AND TRAVEL COST PER PATIENT DAY IN RELATION TO HOSPITAL SIZE.

(and, thus, number and location) of hospitals and ought to be taken into account in areawide planning. As the number of hospital facilities in an area is increased, total travel cost for the area would be expected to decrease as a result of smaller average travel requirements per patient. Additionally, total cost of producing health services within hospitals might initially decrease for the area as the number of facilities is increased due to diseconomies of size associated with excessively large facilities. However, as the number of facilities is continuously expanded, a number would be reached beyond which total health service production cost for the area would rise as a result of both the fixed investment requirement of hospitals and higher variable cost of producing health services in smaller hospital facilities. In Figure 2, line AA represents the relationship between total patient travel cost for an area and the number of hospital facilities, line BB represents total production cost of health services for the area expressed as a function of the number of hospital facilities, and line CC indicates their sum (i.e., total regional access cost).

The problem of minimizing total regional access cost with respect to the number of hospital facilities and locational pattern can be accomplished in four steps. The first step is to obtain a total patient travel cost function for each type of health service that has been minimized with respect to facility locations with varying numbers of hospital facilities. The minimum travel cost function for each type of health service is developed from a matrix of total travel costs per patient from each patient supply area to each potential facility location and a vector of the number of patients in each supply area requiring the health service.

The second step involves the addition of the minimized travel cost functions for each type of health service to obtain a minimized total combined patient travel cost function for the various locational patterns and number of hospital facilities. Computational procedures required to accomplish these two steps are discussed in detail in previous studies [7, 8]. From the above computations, the optimum allocation of patients requiring each type of health service is obtained for the various locational patterns and number of locations.

The third step involves the calculation of the total cost of producing the health services (for each number, locational pattern, and the various sizes of hospital facilities, indicated by the optimum allocation of patients from supply areas to facility locations by the above two computational steps) from a size economies equation estimated for multiple service hospitals.

The final step involves addition of minimized total combined travel cost and areawide total cost of producing the health services to obtain total regional

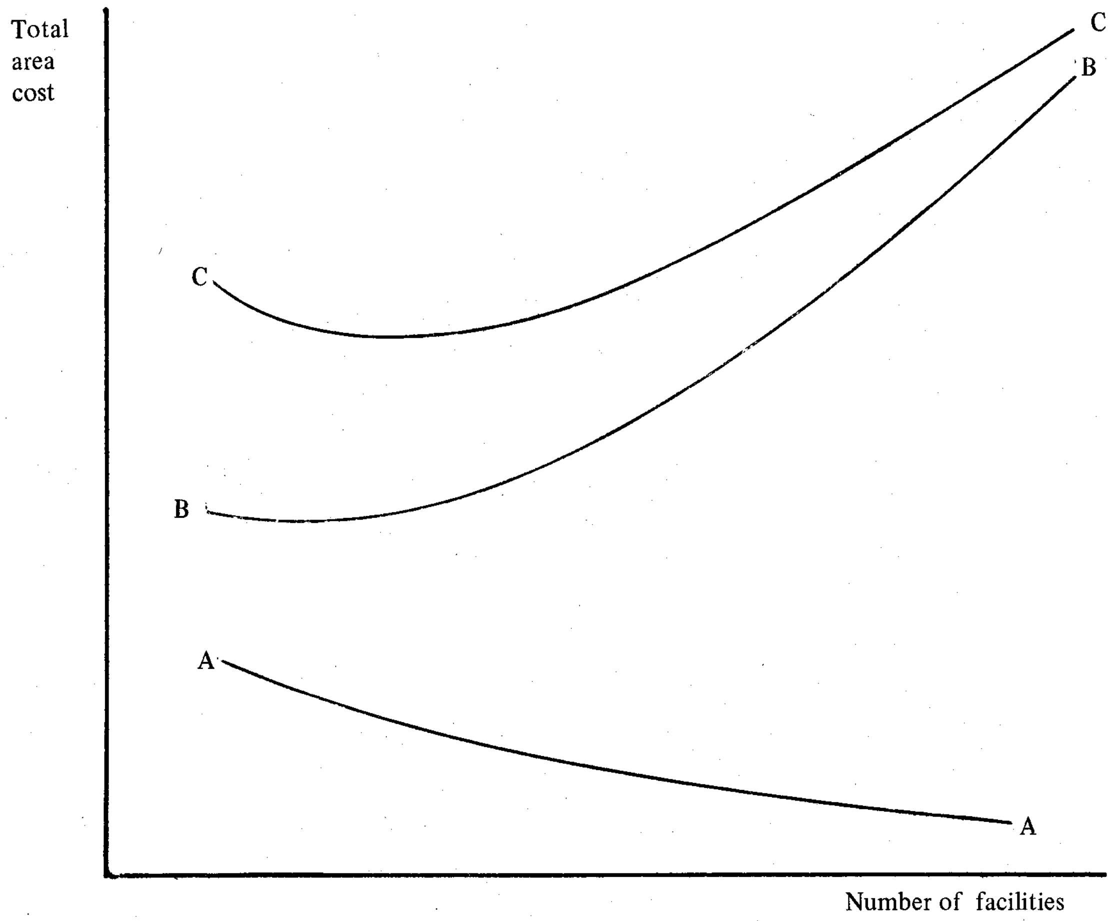

FIGURE 2. TOTAL PRODUCTION AND TRAVEL COST IN RELATION TO NUMBER OF HOSPITALS.

access cost as a function of locational pattern and the number of hospital facilities. The areawide optimum solution is determined where total regional access cost is minimum.

EMPIRICAL USE OF THE MODEL

A study was carried out for a nine county area surrounding the City of Gainesville, Florida. Each county in the study area was designated as a patient supply area and four cities with a 1970 population of 9,000 or more were considered as potential sites for a new multiple service hospital facility or expansion of existing hospital capacity.[2]

Data

Population and Patient Supply. Estimates of the 1980 population for each county were made by adjusting the 1970 Kiplinger [9] estimates for 1980 by the differences in the 1970 Census of Population [10] final counts and the Kiplinger estimates of each county's population in 1970. The proportion of the projected population that would require health services of various types was then determined from information obtained from a 1967 survey of health care practices and needs for counties in Florida [5].

The services considered for this study included inpatient treatment (confinement, diagnoses and treatment) and general outpatient treatment. For inpatient treatment, average length of stay in hospital facilities in the study area was 8.9 days in 1970 which is slightly higher than the 8.2 days of stay for the State [4]. An estimate of 10 days of stay was used for the 1980 projections and reflects the gradually increasing trend in length of stay since Medicare and Medicaid programs were initiated. Estimated additional quantities of each health service required by residents in each county are shown in Table 1.

[2]The study area is a subregion of a 19 county area in Northeast Florida for which a comprehensive analysis is currently underway by Louis Murray, Graduate Research Assistant. In this latter study 15 potential sites for various types of multiple service hospitals are being considered.

Travel Distances and Costs. Patient travel was considered to be by private automobile over hard surface roads from patient supply areas to potential facility locations. The hard surface road mileage from an approximate midpoint location in each census defined enumeration district in each county to each potential facility location was estimated from road maps. Average length of travel for persons residing in each county was computed as follows:

$$(1) \qquad M_{ij} = 2 \sum_{k=1}^{K} P_{ki} M_{kij} \Big/ \sum_{k=1}^{K} P_{ki}$$

where

M_{ij} = average two-way hard surface road mileage from patient supply county i to hospital facility j located at L_j,

P_{ki} = number of persons residing within Enumeration District k of county i in 1970,

M_{kij} = one-way hard surface road mileage from an approximate midpoint location in Enumeration District k of county i to facility j located at L_j.

These computations resulted in a matrix of average travel distances per patient from each county to each potential facility location that was weighted by the 1970 population density of the enumeration districts comprising the county.[3]

Travel by private automobile was considered to cost 20 cents per mile. Thus, the total cost of travel per patient from each county to each potential facility location was estimated as follows:

Table 1. -- ESTIMATED ADDITIONAL QUANTITIES OF HEALTH SERVICES REQUIRED IN THE STUDY AREA BY 1980

Patient supply areas (counties)	Additional amounts of health service needed by 1980		
	Inpatient hospital treatment		Outpatient visits
	Patient days	Patient trips	
Alachua	52,500	5,250	26,000
Bradford	7,500	750	3,600
Clay	16,000	1,600	8,000
Columbia	13,000	1,300	6,300
Gilchrist	1,800	180	900
Levy	6,500	650	3,000
Marion	34,500	3,450	17,000
Putnam	18,000	1,800	9,000
Union	4,000	400	2,000
Totals	153,800	15,380	75,800

[3] I am indebted to Louis Murray for the computation of the average length of travel distances from each county of patient origin to each potential facility location.

Table 2. -- TOTAL COST OF TRAVEL PER PATIENT FROM PATIENT SUPPLY AREAS TO POTENTIAL HOSPITAL FACILITY LOCATIONS

Patient supply areas (counties)	Potential facility locations (cities)			
	Gainesville	Lake City	Ocala	Palatka
Alachua	5.96	17.88	15.28	18.12
Bradford	10.92	12.56	23.40	16.44
Clay	21.12	25.76	25.20	17.20
Columbia	18.80	1.96	31.60	31.00
Gilchrist	13.12	16.28	24.00	31.08
Levy	14.28	25.36	16.40	30.08
Marion	15.92	31.64	5.08	21.96
Putnam	18.68	32.04	22.00	4.72
Union	14.36	10.04	27.20	22.24

(2) $TTC_{mij} = .20\ M_{ij}$

where TTC_{mij} is the total cost per patient for travel from county i to facility j located at L_j to obtain health service m. Total costs of travel per patient from supply areas to potential facility locations are given in Table 2.

Total health service production cost relates to the combined cost of producing both types of services in hospitals of various sizes. For this paper, cost of producing health services in hospitals, as estimated by Carr and Feldstein [1], are adjusted to correspond with 1970 hospital daily service charges.[4] The resulting relationship of adjusted costs to hospital size is as follows:

$$(3)\quad TPC_j = 325{,}062 + 57.59\,(PD_j) + .0000667\,(PD_j)^2 + 9.14\,(OPV_j)$$

where

TPC_j = long-run total production costs for facility j at location L_j,

PD_j = size of hospital facility j located at L_j measured in patient days,

OPV_j = number of outpatient visits at facility j located at L_j.

Results

Total regional access costs were estimated for each of the possible locational patterns with varying numbers of hospital facilities. Cost components for the optimum solutions are summarized in Table 3. The additional quantities of health services can be provided with minimum total access costs to residents in the region by expansion of hospital capacity in two cities, Gainesville and Ocala. With one facility the size required would be an approximate 450 bed hospital. Sizable external costs of patient travel as well as diseconomies to size in the production of the health services are encountered when only one facility is considered. As the number of facilities is increased beyond two, the increased cost of health service production more than offsets the cost savings associated with shorter patient travel distances. The estimated cost savings obtained from the areawide optimum location for two facilities (Gainesville and Ocala) is about $75,000 annually when compared to the optimum location for three facilities (Gainesville, Ocala and Palatka), and about $588,000 annually when compared to the optimum location for one facility (Gainesville).

[4] The function estimated by Carr and Feldstein was:

$$TC = 171{,}085 + 30.31\,(PD) + .0000351\,(PD)^2 + 4.81\,(OPV)$$

The data were for 1963. Estimates of TC were adjusted upward by multiplying each of the terms in the equation by 1.9, the 1970 index of hospital daily charges for the South with the years 1963-64 as the base. In the study by Murray a cost function using data from 67 hospitals in North Florida and South Georgia is being developed for use in the 19 county study area.

TABLE 3.-- OPTIMUM HOSPITAL FACILITY LOCATIONS AND MINIMIZED TOTAL REGIONAL ACCESS COST FOR VARIOUS NUMBERS OF FACILITIES

Number of facil- ities	Optimum loca- tional pattern	Minimized patient travel costs			Joint pro- duction costs	Minimized total regional access costs
		Inpatient treatment	Outpatient visits	Combined travel cost		
1	Gainesville	203,648	1,003,800	1,207,448	11,270,167	12,477,615
2	Gainesville, Ocala	166,250	819,520	985,770	10,903,913	11,889,683
3	Gainesville, Ocala, Palatka	134,850	662,520	797,370	11,167,150	11,964,520
4	Gainsville, Lake City, Ocala, Palatka	111,230	547,788	659,018	11,337,321	11,996,339

It should be emphasized that all residents in the area would not pay the same for inpatient services due to economies and diseconomies of size in service production. For the optimum locations shown in Table 3, costs per patient day range from $67.00 for an approximate 200 bed facility to $78.00 for an approximate 50 bed facility.

CONCLUDING REMARKS

A model permitting minimization of combined patient travel costs and health service production costs with economies to size affecting the level of production costs was presented. This model was used to estimate the optimum number, size and location of hospital facilities and the total regional access costs for projected additional health service requirements in a nine county area. The model appears to have possibilities for aiding in areawide planning of present and future developments in the health services industry.

Some major problems occur in the empirical application of the model. One problem is in acquiring accurate information on the health care needs of a population. Detailed information on the effects of the distribution and characteristics of the population (including race, sex, age, income, residence, etc.) on health practices and the configuration of travel routes is required. A second problem is acquiring information on health service production costs for various service level facilities. However, the possibility of making more productive use of health facility cost functions, patient travel cost functions and other data should encourage an increased effort to acquire more accurate information.

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