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Useful Health Models for Rapidly Changing Areas

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Conditions in many western states are changing rapidly and further changes are anticipated. Planning health services for residents of communities and counties in rapidly changing areas is difficult--but extremely important. Problems in the western states are not unique. For example, states in the Sun Belt are also experiencing rapid growth.

Several models have been developed which provide information to aid local decisionmakers as they make important decisions in planning health services. The objective of this paper is to summarize the models developed and being used in Oklahoma. Four types of models will be discussed: economic models, optimum location models, a regional simulation model, and an impact model.

ECONOMIC MODELS

Local decisionmakers often ask about the cost of providing either emergency medical services (EMS) or health clinic facilities--and how to finance these endeavors.

Emergency Medical Service

The research project for EMS was conducted in 23 counties in southeastern Oklahoma, where EMS providers were interviewed to obtain need and cost information (1). The first component of the research project provides the methodology to predict the number of EMS calls for the service area. The model analyzes calls and groups them according to three types: highway accidents, transfer calls, and other medical calls. The second component of the research project provides the methodology to estimate costs and receipts for alternative delivery systems. To illustrate how the research is used, a recent community application will be discussed (2). In this case, the city council of the community of Newkirk found themselves without EMS service because the neighboring community decided to discontinue serving them.

Using the methodology from the research study, the number of calls they could expect in a year was estimated at 95. Likewise, two alternative annual budgets for EMS service being provided by the fire department were prepared. Yearly costs for Alternative 1 were estimated at $42,438, and $35,595 for Alternative 2. The alternatives differed only in their use of labor. Alternative 2 relied on part-time labor and less full-time labor than Alternative 1. Possible funding sources are fee for service, monthly water meter charges, sales tax, or millage. Revenue schedules were developed for each funding source and for several unit rates.

The information provided the city council was not in the form of recommendations--but rather an analysis of their alternatives. Included in the information provided to the council members was an estimate of the need for the service, an estimate of costs of alternative systems, and alternative revenue sources.

Clinic

Basic research on clinics was conducted by interviewing leaders who had recently constructed community clinics or administrators of community clinics (3). The research yielded a methodology which enables community leaders to estimate the number of physician visits an area can generate in a year, the annual capital and operating costs of a clinic, and revenue necessary to break even. The research material will be applied to a community situation to illustrate how health planners and Extension personnel can use the methodology.

The residents of Ketchum, Oklahoma are without physicians (4). The community is growing and local leaders have identified several physicians who are interested in locating there if clinic facilities are available. Using the methodology developed in the research report (3), and given population estimates by age and sex, the number of annual physician visits which the area will generate is 25,504. This would support 4 or 5 physicians. Two alternatives are presented to local decisionmakers. The first alternative is an unequipped clinic for 4 physicians with a Farmers Home Administration loan. The second alternative is an eqipped clinic for 4 physicians with a commerical loan. With the first alternative, each of the 4 physicians must pay rent equal to $650 per month in order to break even. With the clinic equipped and financed by a conventional loan, $950 rent per month per physician would be required to break even.

Again, the alternatives are not in the form of recommendations, but rather provide economic analysis of the alternatives being considered.

OPTIMUM LOCATION MODELS

Many local decisionmakers ask where to locate an emergency facility. In the case of a single location, the question is where to locate the facility such that the best service is provided. In the case of multiple locations, the question is where are the best locations such that the best service can be provided. In addition, cost and quality information is needed to evaluate whether or not to increase the number of locations. A model has been developed which can answer these questions (5,6). It is a computerized model which minimizes a linear objective function with respect to a specific type of constraint. To illustrate the application of optimum location model, two recent studies will be presented. The first deals with optimum locations of emergency vehicles in Bryan County (7) and the second deals with optimum location of vehicles in the Oklahoma City Emergency Medical Service area (8).

Location of Ambulances in County System

County and city officials in Bryan County contacted the Extension Service requesting an ambulance feasibility study, including information on the location of facilities.

Bryan County decisionmakers had the choice of locating ambulances in a number of communities. Once the supply points were designated, demand areas were delineated by following township lines within the county. The procedure resulted in the creation of 30 demand areas. Road miles from each of the 7 supply points to the center of each demand point were computed to determine a mileage matrix. The only remaining piece of data needed by the location model is the number of annual calls for ambulance service expected from each demand area. In order to minimize the average response time for an ambulance to reach a patient, weight is given each demand area, depending upon the expected number of calls for service and distance from each location. The locations selected by the computer model were presented to local officials along with some quality-of-service variables for each location.

Bryan County decisionmakers need to decide whether they will have two or three ambulance locations in their county. With three locations, the average one-way distance to reach an emergency is 1.6 miles, compared to an average 2.4 miles with two ambulance locations. A budget analysis for both situations will be presented. Costs are taken from an earlier study of 23 counties in southeastern Oklahoma, in which ambulance operators estimated operating costs while equipment dealers estimated capital costs (1).

Two Locations--Alternative 1. It was assumed that 5 hightop vans would be used, costing about $21,000 apiece. These 5 vehicles would travel a total of 66,000 miles per year. This means a new vehicle would be bought by the system every 14 months. The depreciation on these vehicles would be $18,486 annually. A VHF radio would be needed for each vehicle, costing about $2,200. They have a recommended life of 10 years.

A base communications system was also needed in the county, at a cost of about $5,300. It also has a 10-year life. A tower would be needed to boost the signal to get countywide coverage. A 150-foot tower would cost about $2,920, including antenna, wiring, and installation. This tower has a 20-year life. Both the tower and the base communications equipment could be used in the provision of other county services such as law enforcement and fire protection.

It was assumed that a $50,000 building would be built to house the emergency vehicles and personnel. If money were borrowed on a 40-year, 6-percent Farmers Home Administration loan, the payments would be $3,323 annually.

Eleven pagers were included in this budget. They cost about $375 each and have a 3-year life. Five first-responder kits were also included. They are to be used by trained persons in more remote locations to stabilize patients until a vehicle arrives. They cost about $750 each and have a recommended life of 5 years. Total capital costs were $25,710.

It was estimated by operators that hightop vans get about 9 miles to the gallon. If 66,000 miles are to be travelled in 1980 and gasoline averages $1.40 a gallon, gasoline costs will be about $10,267 in

1980. Vehicle maintenance includes such things as oil, tires, tune-ups, and insurance. It is also based on mileage and is estimated at $9,114 for 1980.

Vehicle communications maintenance and service costs are based on the costs for a service contract per unit, per year. This cost is about $90 per unit. Base communications maintenance costs were estimated in a like manner at $398.

It was assumed a second building could be rented in another community for $75 a month. Utilities and maintenance were estimated at $1,591, on the basis of the type of building and its age and use. Insurance on the building at the first location was estimated on the basis of its insured value of $50,000.

Medical costs include such items as bandages, medical equipment maintenance, and linens. These are estimated on the basis of the number of expected calls. This cost was estimated at $10,147 for 1980.

It was assumed that a manager could be hired to run the service for $1,000 a month. Eight emergency medical technicians at $4.50 an hour were also assumed to be hired. One of these would be stationed at the second location. The rest of the labor at that site would be provided by volunteers. Two of these volunteers per week would be on call to respond with the full-time individual. They would be paid $50 per week stand-by pay and $4.50 per hour when they respond. All labor charges include a 15-percent charge for employer's overhead for such things as Workmen's Compensation and Social Security. A training and miscellaneous charge brought operating costs to $141,809 and total costs to $167,519.

Three Locations--Alternative 2. This alternative follows the same procedure as did the first alternative with two locations. It is assumed that 6 vehicles will be needed--3 at the primary base site, 2 at the second site, and 1 at a third site. Six vehicle radios, a base station, a tower, one building at the primary site and 13 pagers were included. It was assumed that one less first-responder kit would be needed with the addition of a third location. Capital costs totaled $26,073.

It was assumed that a building could be rented at the third site for $50 a month. Utilities also would have to be paid. Vehicle costs and medical costs were unchanged from the two-location alternative. Nine emergency medical technicians were assumed to be hired--7 at the primary site, 1 at the second site, and 1 at the thirdsite. Volunteers were used at the second and third sites and were paid as they were with the two-location alternative. Operating costs were $161,545, and total costs were $187,618.

An estimate of county revenue can also be made. This can be done by multiplying the 1,812 expected calls by several base rates and adding a mileage charge. If this were done using a $50 base rate and a $2 a mile for one-way, per-patient charge, total charges would be $131,600. All people do not pay their bills, however. If collections were 70 percent, $92,120 would be collected.

The county may also pass a special millage to support their service. Three mills would bring about $119,340 in revenue.

Revenue may then be compared with costs. If a $522 3-mill tax were to pass in Bryan County, a $50 base rate with a $2-per-mile charge would cover any of the alternatives presented and allow for added costs due to inflation.

Optimum Ambulance Locations Depending Upon Useage Needs

Oklahoma City Ambulance administrators were concerned about providing quality ambulance service within their financial constraints. They asked Extension for assistance in completing a study to determine how many ambulances would be needed and where they should be at various times during the day to provide the desired quality of service. At that time, the service was operating from 10 locations, 24 hours a day.

When the project was initiated, Oklahoma City Ambulance personnel indicated that there were 11 possible locations from which they had permission or facilities to operate vehicles. In addition to identifying possible vehicle locations, a detailed analysis was completed of the ambulance runs made during the preceeding year (8). The analysis showed that the frequency of runs from 7 p.m. to 11 p.m. was less than from 7 a.m. to 7 p.m. In addition, the frequency of runs from 11 p.m. to 7 a.m. was even fewer than both periods above. Thus, if the ambulances are properly placed, fewer locations should still be able to provide the same quality of service.

To aid the decisionmakers, the objective was to select the best 10, 9, 8, 7, and 6 locations for providing service from 7 p.m. to 7 a.m. and also to select the best 10, 9, 8, 7, 6, and 5 locations for providing service from 11 p.m. to 7 a.m. Before proceeding with the results, the assumptions and data will be discussed.

Locations Analysis. Once the 11 possible supply points were designated, demand areas had to be delineated. For this, the Oklahoma City Ambulance service area was delineated into 85 demand areas, each of which was approximately 2 miles square. Road miles from each of the 11 supply points to the center of each demand point were computed to determine the mileage matrix. The number of calls for each demand area were also estimated from Oklahoma City Ambulance records.

One objective function was evaluated due to the extreme costs in running the large computer model. The objective function was to locate the stations which would minimize the average response time to reach an emergency. The computer program calculates a complete enumeration of all possible combinations of locations for the 7 p.m. to 7 a.m. and the 11 p.m. to 7 a.m. shifts.

Specifically, the solution to minimize average response time for the 7 p.m. to 7 a.m. shift required that all possible combinations of problems be computed for 10, 9, 8, 7, and 6 locations respectively. These combinations are: $C\binom{11}{10} = 11$, $C\binom{11}{9} = 55$, $C\binom{11}{8} = 165$, $C\binom{11}{7} = 330$, and $C\binom{11}{6} = 462$, or a total of 1,023 combinations of locations. By doing the same analysis for the 11 p.m. to 7 a.m. shift and including $C\binom{11}{5} = 462$ for 5 locations as well, the total number of combinations the computer solved is 2,508. As the number of locations decrease, the average miles to reach an emergency increase. Also, with the reduced number of locations, the probability of two calls occuring at the same time increases, forcing a more distant ambulance to respond. The output from the computer program used to select where to locate ambulances also identifies which areas should be served by which location. Probabilities can be used to calculate the number of times that the ambulance in a designated service area is out on a call and a second call occurs. For example, if 7 locations are desired, on 755 occasions each year a call will arrive when the closest vehicle is out on call. This is a little deceptive since neighboring locations are available to respond if a certain vehicle is out on call. The number of times that, say, three vehicles in a certain area of town are all out on call when a fourth call arrives is very low.

Analysis of Costs Savings. By reducing the number of locations, the person-hours needed are reduced. Of course, decisionmakers must weigh the difference between reduced coverage from fewer locations and reduced costs. For example, if nine locations are operated from 7 p.m. to 7 a.m. rather than the present 10 locations, person-hours needed per year are decreased by 8,736 hours, and yearly costs are reduced by $36,364. Total personnel cost savings resulting from changing from 10 to 7 locations is $109,092.

A possible alternative to simply reducing the number of locations would be to reduce the number of locations and make a transfer vehicle available. The transfer ambulance would handle nonemergency-type calls. Thus the ambulances at other locations would be available for emergency runs.

SIMULATION MODEL

The simulation model is unique in its simultaneous consideration of several health services and their constraining effects on one another (9). Its joint consideration of spatial effects and different services make it much more complete than models considering only one of these aspects.

The major purpose of the 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 model focuses on the spatial usage of health resources in a multicounty area. A spatial equilibrium model using linear programming is established with several alternative objective functions considered.

The solution technique used for the model is mixed integer linear programming. Linear programming is chosen because it has the capacity of handling a large problem for low cost, yet it can include most of the features appropriate for inclusion in this model. Other methods, such as quadratic programming or simulation, could handle the same problem and include additional features of the health care system, but only at considerable cost in programming time and money. Mixed integer linear programming is used when new investment is considered. This allows the limitation of investment to integral units, rather than the continuous units required by ordinary linear programming.

Overview

An overview of the relationships in the model is shown in Figure 1. The model is divided into two major sectors--a supply sector and a demand sector--with the interaction between the sectors determining how demand is satisfied. In this hypothetical system there are two locations, A and B, and two services, I and II. Beginning with information concerning the characteristics of the population, the health facilities, and the health personnel for each location, a solution is reached in which all the demand for health services I and II is satisfied, either by existing facilities and personnel or through investment in additional facilities or hiring of more personnel.

Demand Sector. Population statistics are the primary input data for the incidence model. The model multiplies the susceptibility of each subset of the population to various ailments by the size of these population subsets, yielding the expected incidence of these ailments in cases per year for the population in question. For example, suppose location A has 40 men from ages 45 to 64. This population group has an average incidence of circulatory system problems requiring hospitalization of 40.6 cases per 1,000 population per year. Therefore the 40 men in this group in location A would be expected to have 1,624 cases of circulatory system problems per year. The incidence model generates a similar figure for several population subsets and ailment categories. These incidence numbers are inputs for the care regimen model and yield an expected annual demand for each type of health service by the residents of each location. This demand is assumed not to be a function of price. Residents satisfy this demand by choosing between the alternative sources of supply of that service, subject to any constraints imposed by their needs for accompanying service, basing their decision on the criterion implied by the applicable objective function.

Supply Sector. 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 additional units of supply are obtained or not depends on the value of the objective function with local supply versus its value with the extra travel required when insufficient supplies are available locally.

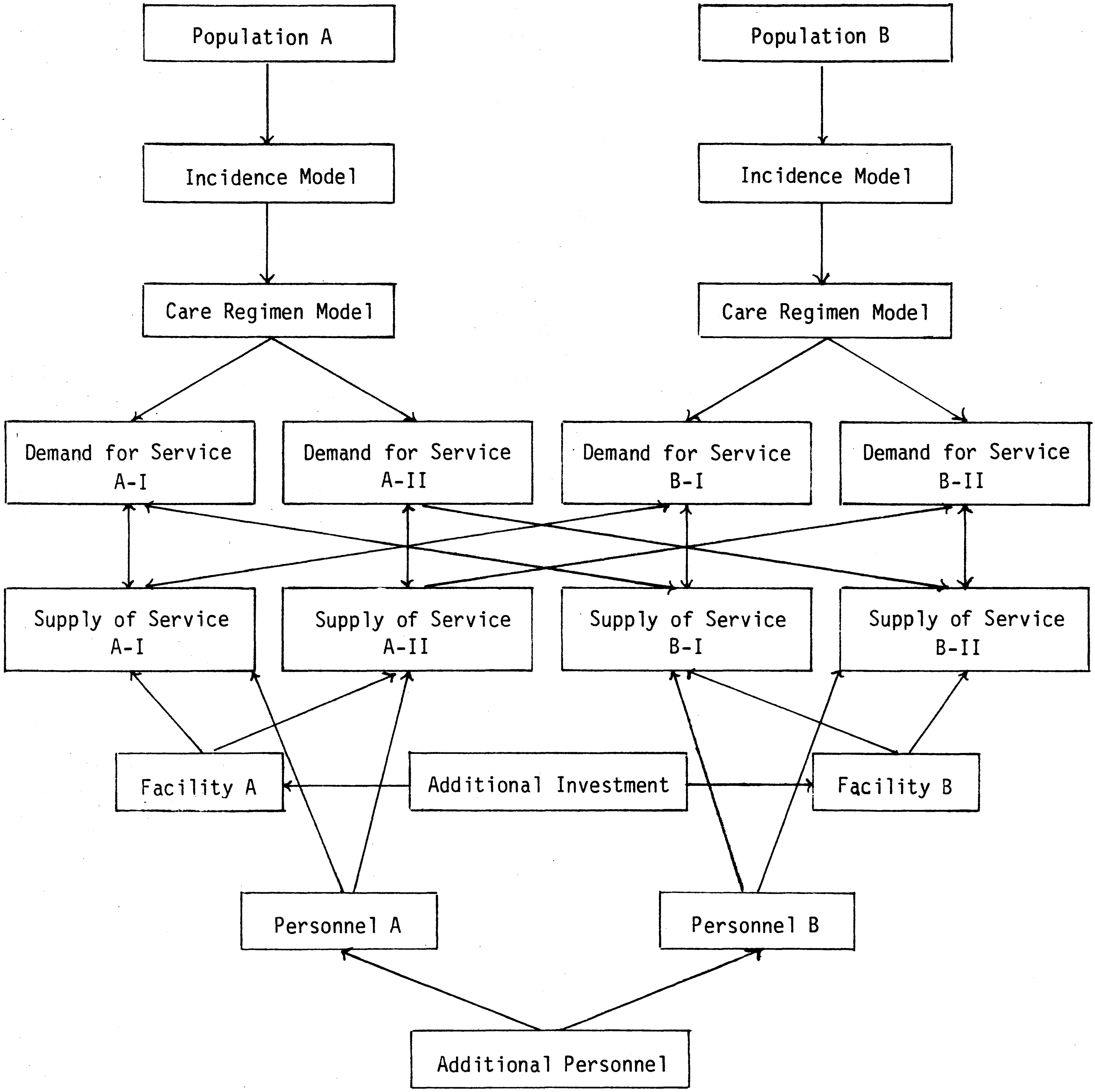

Figure 1. System relationships for the two-location, two-service case.

Model Application

The model will be demonstrated using a health planning area in northwestern Oklahoma. Five interrelated services are included in the analysis: (1) ambulatory care, or physician office visits; (2) ambulance service; (3) emergency room service; (4) primary hospital care days; and (5) specialized hospital care days, a combination of secondary and tertiary care days. The model is run for each of the 5 objective functions such that the demand for the 5 services from the 27 demand locations are satisfied by 46 supply locations. The supply locations include three locations not in the study area but often used by area residents for specialized care and residual demand.

Data from the model provides projections of the number of patient days, ambulance calls, emergency room visits, physician office visits, and nurses in projects for 1980, 1985, 1990, and 1995. With these long range estimates, local and regional decisionmakers can plan for the capital outlays and health care personnel needs of a region.

MEASURING THE IMPACT OF A HOSPITAL ON THE COMMUNITY

Local decisionmakers in Perry, Oklahoma requested the measurement of the economic impact of their hospital on the community (10). There was some fear that the hospital would close.

The business activities of Perry Memorial Hospital, together with the consumption transactions made by hospital employees, create substantial secondary economy effects within the Perry area economy. A common measure of such economic activity is called a multiplier. A multiplier indicates the relationship beteen some observed change in an economy and the amount of economic activity that this change creates throughout the economy. The local employment multiplier for the Perry Municipal Hospital is estimated as 1.34. This means that if the hospital employment is increased or decreased by 1 job, 0.34 other jobs will be created or lost, respectively, in the local economy. If the hospital should cease operations, 62 hospital jobs would be lost to the community. Over the long run, 21 secondary jobs would also be lost to the local economy.[1]

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1. Multipliers taken from Doeksen, et. al. "Multipliers of Agriculture and Other Industries," OSU Extension Facts No. 821, Oklahoma State University, Stillwater, 1976.

The local income multiplier for the Perry Municipal Hospital is estimated at 1.50. Thus if the hospital should cease operations, the community's loss of $276,898 in annual hospital income would, over the long run, cause the loss of an additional $138,449 in annual secondary income in the local economy. The total loss to the Perry area economy would be $415,347 per year.

The decline in local population if Perry Memorial Hospital should cease operations was estimated at 83 persons. The hospital is a major employer of persons who take jobs to supplement their family income. It was assumed that few, if any, of these persons would leave Perry if the hospital ceased operations. So, while 62 hospital jobs would be lost, and an equal number of families would suffer reduced incomes, it was estimated that only 33 people who are either employed by the hospital or whose household breadwinners are employed by the hospital would move away. It was estimated that, if the hospital should close, 50 persons would leave the Perry area in the long run because their jobs or the jobs of their household breadwinners would be eliminated due to the decreased local economic activity associated with the closing of the hospital. Decreases in employment, income, and population accompanying local public sector impacts of closing the hospital would cause reduced local sales and thus reduced local sales tax collections.

Decreased business activity would reduce other types of local tax receipts--including, over the long run, ad-valorem taxes. The total local tax receipts reduction associated with closing Perry Municipal Hospital was estimated as $23,023 per year.

SUMMARY

This paper briefly reviews the research completed in Oklahoma and the application of the research to local problems. The success of the program is due mainly to the team effort associated with each study. Health Systems Agency and/or Emergency Medical Service Division personnel were involved with the research projects. By having them participate, the research is made more relevant and useful. This ensures that the research will be used. The team approach is also used in conducting community studies. For example, if a community requests an emergency medical service study, a team consisting of a Health System Agency person, a representative from the State Emergency Medical Service office, and one from the Extension office meet with the local leaders concerning the problem. If any of the above models are desired, the Extension person will complete the study and the team will present the results at a second meeting.

This approach has proven to be very popular with the local decisionmakers in Oklahoma . At this writing the team is handling about one request per week. This is possible because the models above are computerized (11 and 12) and quick turnaround is possible.

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