ECONOMIC ANALYSIS OF CURRENT AND FUTURE NEEDS

FOR EMERGENCY MEDICAL SERVICE SYSTEMS

IN THE STATE OF OKLAHOMA

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CHAPTER I

INTRODUCTION

Need for the Study

Highway accidents and other medical emergencies in the State of Oklahoma are occuring in an increasing number each year. According to the Oklahoma Department of Public Safety [60] the traffic trend for the State between the years 1969-1980 shows an increase in the number of accidents, injured cases and deaths by 22 percent, 12 percent and 8 percent respectively. The daily traffic accident toll shows there were 234 accidents or 1 accident every 6.1 minutes; 2.7 fatalities or 1 case every 9 hours; 95 injuries or 1 case every 16 minutes. The total economic loss in terms of wages, medical expenses, property repairs, replacement cost, and insurance administrative cost for that same year was estimated to be over 463 million dollars. Other medical emergencies that include heart attack, stroke, home or industrial accidents are also among the leading causes of death [62]. As a result, the provision of adequate emergency medical service (EMS) in the state has become a very important component in the planning of the general health care system [63].

In 1966, nationwide legislation (PL-89-564) entitled " The National

Highway Safety Act of 1966" was passed requiring states to have a highway safety program developed in accordance with uniform standards designed by the Secretary of Transportation. Standard 11 of that act focused on the importance and requirements of planning for emergency medical services. Because of this legislation, Oklahoma is making a statewide effort to improve the life-saving capability of emergency medical services through personnel training, proper equipment, communications, operational coordination, comprehensive planning and research.

As a consequence, many EMS systems are being analyzed each year by local officials as they attempt to provide EMS within their budget constraints. This is evidenced by the fact that the Emergency Medical Service Division of the State Health Department and the Oklahoma State University Cooperative Extension Service completed 110 county and community EMS studies in 1980, 1981 and the first 9 months of 1982.[1] The studies are a response to inquiries by local decisionmakers for: (1) current and future EMS needs; (2) optimum location of services; and (3) estimated costs and revenues of alternative EMS systmes. This information is provided in the county and community studies.

As local systems are being planned, problems arise because local decisionmakers do not look at the "big picture". For instance, a county system organized under the Rural Ambulance Service District Act [21] allows the creation of an EMS district funded by ad valorem taxes. This

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[1] For a copy of any of these studies, contact Leonard Anderson (Oklahoma State Health Department) or Gerald Doeksen, Agricultural Economics Department, Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma.

act allows the creation of EMS district for areas under 8,500 population and permits limited taxation for the support of the EMS system created. The community organizes an EMS district containing their school district which is in both counties. Since the neighboring county system was organized first, it collects the millage for the county but since the community just across the county line is much closer to the people, the residents call this system for service. In essence, the residents in the county near the community in the other county are paying taxes to the county system but receiving services from the community system in another county. An equitable solution to the problem has not at this time been reached. If a complete analysis had been undertaken the problem could have been brought to the attention of the county officials and the current problem may have been avoided.

The need for comprehensive regional and/or state study is evident in the above situation. As more EMS districts are organized, problems like the one discussesd above will become more numercus. This research is intended to assist local decisionmakers as they plan EMS systems and also provide information to state planners as they work with local groups.

Objectives

The overall objective of this research is to develop planning tools for EMS systems in the State of Oklahoma. It is mainly designed to provide information which can be used by EMS planners as well as local decisionmakers as they plan for efficient, effective and equitable EMS systems within their financial constraints. More specifically the objectives are:

1. Devising methods to analyze a county EMS system. This involves:

   a. determining the expected number of current and future EMS calls;

   b. determining optimum loction(s) for ambulances;

   c. estimating costs and revenues of alternative EMS systems; and

   d. estimating the number of times multiple EMS calls can be expected to occur.

2. Devising methods to analyze regional and statewide EMS systems. This includes:

   a. determining optimum locations for basic life support systems (BLS), first responder systems (FRS) and advanced life support systems (ALS) at the regional level;

   b. estimating average response time, maximum response time and expected number of EMS calls at the regional level;

   c. estimating the expected number of current and future EMS calls at the state level;

   d. designating service demand locations by EMS areas at the state level using minimum average response time as criterion.

The Study Area

Seventy-five counties, consisting of about 66 percent of the population of the State of Oklahoma were included in this study. Oklahoma and Tulsa counties were excluded because they are metropolitan counties and the emphasis of this research is on rural and semi-rural counties.

The State is facing an upward trend in population growth. Based on the statistics of the Bureau of Census [85], the State's growth rate was 1.82 percent per year between the years 1970 and 1980. Without including Oklahoma and Tulsa, the rest of the area grew by 2.2 percent per year during that period.

In 1980 there were a total of 173 EMS facilities in 164 locations. This is based on the 1980 EMS Registry [58]. There were 118 (68 percent) of the basic ambulance services, 47 (27 percent) basic life support systems, 6 (3 percent) advanced life support systems. The rest were either special or uncategorized. About 22 percent were public, 16 percent private, 13 percent hospital based, 11 percent funeral homes. The rest were either volunteer, paid volunteer, volunteer fire department, paid fire department, etc. In regard to management, 67 (39 percent) were city managed, 32 (19 percent) private and the rest were funeral homes, hospitals, county, etc. Methods of financing varied. Forty-nine percent used charges; 24 percent use city subsidy, county subsidy or both; and the other 27 percent used other methods such as ad valorem tax and the like.

CHAPTER II

REVIEW OF LITERATURE

As local leaders plan EMS systems, many cirtical questions arise concerning (1) future needs for the service; (2) best location(s) of EMS facilities (first responders or advanced life support systems); (3) costs and revenues of alternative systems; and (4) the probability that the system will be adequate to meet most emergencies. At a broader level is also another problem related to equity which defines the relationship between those who pay for and those who benefit from a given service system. This problem often arises because local decisionmakers do not look at the entire service area to be covered especially when such services cross county lines.

The focus of this Chapter will be the theoretical and empirical aspects of the problems posed above. First, the development of systems analysis will be discussed. The area of EMS demand analysis will be considered next. As a third aspect of importance, the area of optimal location of service facilities will be reviewed, followed by a discussion of the relevance of probability theory in EMS analysis.

Emergency Medical Service System Planning

For many years, EMS systems planning had taken a back seat to other national problems. The lack of serious attention to this problem was first documented by the National Academy of Sciences [56] whose recommendations became a precursor to the development of emergency care planning. The Highway Safety Act of 1966 created a Federal-State-local partnership to improve and expand safety programs. Among these programs, standard 11 specified that

> Emergency Medical Service is to provide an emergency care system for quick identification and response to accident injuries, to sustain life through first aid and to coordinate the transportation and communication necessary to deliver definitive medical care to the injured in the shortest possible time [87, P. 42]

One source of stimulus for a systems approach to EMS was the "Emergency Medical Service System Act of 1973," enacted by the U.S. Congress. It was set up to provide direction and funds for a system approach in establishing emergency medical services.

The State of Oklahoma, among other states of the nation, is working under its own laws concerning EMS to have effective, efficient and equitable EMS systems in the state. The system approach developed by Doeksen et al. [21] now provides an excellent guide for EMS operation especially for rural and semi-rural environment typical of much of Oklahoma. It places emphasis on a holistic approach to problem solving. This includes the need for common understanding of EMS problems by the people concerned especially EMS operators, state planners, researchers and the public. The use of proper analytical tools to solve common problems is also emphasized. Since the purpose of an EMS System is to create a coordinated response to the immediate needs of an emergency patient, its planners are expected to consider and provide a coordinated working relationship with hospitals, public service agencies and the like.

Theoretical and Empirical Studies of EMS Utilization

In conventional microeconomic theory, a rational consumer chooses a set of goods and services in order to maximize his/her welfare or utility subject to budget constraints. This would provide a procedure for deriving the individual's demand function by hypothesizing that demand for a given good and/or service is related to the price of the product, the price of competitive or substitute goods and services, income of the individual and/or other relevant variable(s) such as tastes and preferences of consumers [84]. Such theory assumes, among other things, that given all relevant information at a given time and space, the individual consumer is capable of evaluating prices and quality in making a choice of that particular product. However, emergency service is not provided on the basis of user's ability and willingness to pay.

On the supply side, the theory of the firm assumes that a producer maximizes profit subject to cost constraints or minimize costs subject to one's production function. This leads to the procedure of deriving the supply function of the firm which will show the ability and willingness of the supplier to provide the product at alternative prices. The interaction of supply and demand determines the equilibrium price and quantity of a good and/or service.

The economics of the general health care system is much more complex than can be represented using the simple behavioral theories of the consumer and the firm described above. The complication arises due to the nature of EMS demand, market imperfection in the production and distribution of health services, third party settlements, subsides, etc.

In studying theoretical health service analysis, very little attention has been given to emergency medical services. They are either assumed implicitly in the health service category or not considered at all. Examples of such studies include that of Newhouse; Manning, et al.; Sotddart and Barer; Intrilligator [98]. The work of Grossman [32] also provides insight to the theoretical approach to health care demand in general form.

Empirical studies for EMS demand for either urban or rural areas have been made in the recent past using one or a combination of factors related to sociodemographic and economic characteristics [1, 15, 16, 19, 20, 22, 48]. One of the earliest EMS guidelines emerged in 1968 by Dunlop and Associates [22] which suggested that EMS needs can be estimated using the size of population of a given area. The study was based on a survey of some 80 ambulance services in the United States. According to this study two equations were estimated. One equation was used for predicting EMS calls for areas of population under 10,000 and the other for areas of population extending over 10,000. About three years later, Aldrich et al. [1] used data relating to a currently operating public emergency ambulance and developed a model to predict and explain the variation in the number of various types of emergency calls in the Los Angeles area. The linear regression model included 26 exogenious variables related to social, demographic, and economic indicators such as housing density per capita, acreage per capita, race, age, marital and employment status. The model was used to predict total demand, auto accidents, cardiac arrests, poison, other illnesses and the number of "dry runs." Models like this typically encounter the problems of multicollinearity and lack of appropriate data. Data from 1960 census are used to represent that of 1964-1967.

Along similar lines, first and second order regression models were used in two studies to predict and explain EMS call rates for a large metropolitan hospital in Atlanta by Deems [19] and Kvålseth [48]. Multivariates related to social, economic, land-use and transportation were employed as exogeneous variables. Unlike that of Aldrich, et al. [1], they used exogenous variables whose values were derived during the same period as the endogeneous variables and emphasized the relative importance of each exogeneous variable in terms of its contribution to the variation in each classification of ambulance calls. Individual models were formulated through stepwise regression for different types of emergencies and obtained highly significant fits.

King and Sox [42] attempted to do a systems analysis of the operations of EMS in the San Francisco area with specific objectives of: (1) determining the rate and distribution of emergencies and the sequence of time from occurance of injury to discharge of the patient and (2) analyzing cases of patients who were dead on arrival. While the study provided an investigation of an EMS system in terms of its components and their interrelations, the predictive mathematical model is not clearily or explicitly presented.

In general most of these studies presented the same conclusion. The number of EMS calls per unit time is highly predictable by using social, economic and geographic variables. A detailed treatment of such studies can be found in Andrews [2].

Doeksen et al. [20] in their pioneering study of EMS Systems in Oklahoma's Great Plains provide procedure for estimating emergency medical service calls that can be easily used by local decisionmakers. Ambulance calls are classified into three types: (1) highway accidents; (2) transfer calls (hospital-to-hospital); and (3) other medical calls related to heart attack, stroke, home or indstrial accidents and other illnesses). For highway accident calls, data from the Oklahoma Department of Highway were obtained to determine average number of highway injuries. Transfer calls were estimated using local hospital data and/or information provided by ambulance operators. Finally, utilization rate for other medical calls were determined according to the distribution of population by age cohorts. All utilization rates are occasionally updated as seen in [21].

The study of Daberkow and King [16] is another example where population is used as an independent variable to estimate total EMS calls. Number of calls per 1000 population was regressed against area population with and without intercepts for two situations. The first one was used to estimate calls for all counties in California and the second was used for the rural areas of the state.

Factors such as price and income levels have received very little attention in the determination of EMS calls. In fact demand for emergency care is hypothesized to be insensitive to price and income. However, if one had to classify all EMS calls into a real or life-threatening emergency and one that is less critical, the case of a real emergency may be considered perfectly ineleastic with respect to price, price of a competitive (substitute) good and/or income. A similar assumption is made by Dabarkow and King [16]. In a non-emergency situation however, a patient may be able to evaluate alternatives, given sufficient knowledge about other services with respect to his/her income and price of the service. In this situation a downward sloping demand curve as exemplified by Intrilligator [99] may be appropriate.

Another dimension to be considered in the analysis of EMS calls is the demand for ambulance service to be generated at random defined by some known probability distribution. Dearing and Jarvis [17] in their location model assume stochastic demand a queuing model. Similarly Dunn [23] included a one-ambulance server queueing model in his health service analysis and was able to determine the probability of excess demand, i.e. the number of multiple calls that will be generated while the ambulance is out on service. To find capacity, the excess demand probability is related to average demand. This kind of analysis has an important place in the decisionmaking process of EMS planners especially in evaluating the sufficiency of the current service. A very high probability of a busy period for an ambulance system would mean a consideration for an additional unit to handle the excess demand and reduce the number of people waiting for service. This is one reason why a method to accurately determine current and future demand for EMS would be useful.

Location-Allocation Models

General

Location-allocation problems are generally classified into two major categories. The first problem is one concerning a location on a plane characterized by infinite solution space whereby central facilities may be located anywhere on the plane and are not limited to any of the nodes of the network or to points on the links between the nodes. The second category falls into location allocation problem on a network where a solution space consisting of points on the network is considered and distance or time is measured along the network [61].

In a Weberian location model, the concept is focused on a point M to be located such that the sum of the distances from point M to the three vertices of a triangle is minimum. As an illustration, two points A and B are to be considered as locations of two sources of raw materials and a third point C is the marketing location. If W_1 and W_2 are the weights of raw materials required from sources A and B to produce W_3 units of output, where should the plant be located? According to this model, the plant M is determined by the lowest value of the sum of the transporation costs which is $W_1d_1+W_2d_2+W_2$

d_3, where d_1, d_2, and d_3 are the distances from M to A, B and C respectively. This model can be extended to handle more than three locations and multiple sources and an algorithm for the numerical solution of such a problem is developed by Kuhi and Kuenne [47].

Weslowsky and Love [96] present a model for optimally locating any number of new facilities in relation to any number of existing facilities. Their objective was to minimize total load-times-distance costs in the system by considering rectangular distances as opposed to Euclidean Straight-line distance.

Cooper [12] examines the problem of simultaneous source determination and suggests an approach for solving a certain class of location-allocation problems. Given (1) the location of each destination; (2) the requirements at each destination and (3) a set of shipping costs; the problem is to determine the number of sources and the end capacity location of each source. Both exact external equations and heuristic method are presented for solving these type of problems.

The major concern in the development of location-allocation models evolves from the interest of allocating scarce resources among competing ends. Linear programming is one of the set of analytic tools used to handle such problems. Hitchcock [38] and Koopmans [44] take credit for their independent formulation of a special transportation method of linear programming. In the model, a homogeneous product of a specified amount is to be shipped from "M" origins to "N" destinations. The problem is to find the amount "X_{ij}" to be shipped such that the total cost of transportation is minimized. Koopmans [44] applied this theory of optimum resource allocation to the shipping industry to determine the most efficient use of transportation vehicles. Further, Dantzig [16] found it useful to reformulate the problem in terms of a system of activities with various items in common. The solution procedure, known as the simplex technique, makes it possible for solving transportation type problems that involve a large number of constraints and unknowns.

Another important contribution in the area of location analysis is that of Stollsteimer [77]. The complete enumeration method under certain restrictions, permits the determination of the number, size and location of plants which minimize total cost given total quantity of raw materials produced in varying quantities at different production points. The inclusion of plant numbers and locations as variables and the consideration of economies of scale in plant cost are the distinguishing characteristics of the model. Even though the procedure does not consider a system that minimizes assembly, processing and distribution costs simultaneously, it has gained popularity in the general area of plant location analysis.

Solution procedures for transportation problems are varied and range from simple to complex. Such methods like tree-searching, branch-and-bound and heuristic programming are summarized by Scott [70]. An algorithm developed by Brandt and Intrator [8] for example, deals with a large transportation problem where the number of destinations is much larger than the number of origins. The problem was a typical minimization of costs subject to constraints.

The area of political "districting" or redistricting has also been handled in the general lcoation-allocation problem. The nature of the problem is summarized by Scott [70] as follows:

> ... given a set of n sub-regions, each with a given population P_j, the problem is to aggregate the subregions into m major electoral districts or constituencies, so as to make interdistrict variation of population minimally small (P. 115).

Along similar lines, Marlin [53] describes a procedure of partitioning an area containing many geographical locations each with an associated activity or work load into districts called "tours." The objective was to assign each location to a tour such that the total workload assigned to each tour falls within a specified limit and the total cost to service the locations is minimized.

Warehouse location problems have also been studied in great detail. For example, Maranzana [52] used a heuristic method to locate a given number of warehouses to serve a certain region of known demands by minimizing transport costs. Hueristic methods are a set of rules for the solution of a given problem where an acceptable goal is to obtain a reasonable solution as opposed to optimal solution. Another example is to be found in Kuehn and Hamberger [46]. The problem was to determine the geographical pattern of warehouse locations which will be more profitable to a company by equating marginal cost of warehouse operations with transportation cost savings and additional profits that would result from more rapid delivery. First, a finite number of sites is chosen to serve as potential locations for a set of central facilities. By locating the central facilities iteretively, the ones resulting in the greatest improvement in the value of the objective function is chosen. A more general heuristic method for solving location-allocation problems is proposed by Cooper [12].

Location Models Related to Emergency Mecical Services

In the late 1965, Mitchel [54] evoked the lack of attention ambulance services deserve. He pointed out four areas or phases of problems that consist of (1) epidemiology; (2) patterns of ambulance service; (3) geographic and logistic; and (4) economic. Among these, the second and third could be associated with the problem of optimal location of EMS systems. The Division of EMS, Oklahoma State Department of Health has also recognized the fact that ambulances in the state as a whole are not optimally located to provide statewide coverage [63]. Consequently, optimal locations of EMS systems is becoming part and parcel of a comprehensive EMS planning and analysis in the State as evidenced in the works by Doeksen, Frye and Green [20], Doeksen, Anderson and Lenard [21], Nelson and Doeksen [57], Oehrtman [58] and Oehrtman et al. [59]. This is a constructive effort to provide efficient, effective and equitable emergency systems for the public.

A typical problem of optimum location analysis has been well stated by ReVelle et al. [67] in their analysis of private and public sector location models. The problem statement and objective are stated as follows:

> Given a number of demand areas for a certain product, each with a demand D_i; and a number of alternative sites where facilities may be built to satisfy these demands, determine where the facilities should be placed and which demand areas are to be served by a given facility. The objective is that the sum of the transportation cost and the amortized facility cost is minimized [p. 697].

Even though the above problem was stated for a warehouse or plant location, it has important implication for the location problems of EMS facilities.

Solution methods have been suggested by many. For example, Toregas et al. [82] uses a linear programming technique to obtain the minimum number of facilities and their locations such that each point of demand has a facility within 'S' time units. The objective function was set by assuming costs to be identical for all possible facility locations. From this, the number and location of the facilities that provide the desired service were obtained.

The problem described as "Location Set Covering Problem (LSCP) was further developed by Toregas and Revelle [81] whereby a procedure known as "Reductions" is used to solve the location problem. The idea of the model is to identify the minimum number of location of facilities such that no demand point will be in an area that is farther than the maximal service distance from a facility within 'S' time units. At least one site is chosen from all eligible locations in each set and thus coverage of each demand point is insured. Maximum distance or time is taken to be an important parameter. The solution of the LSCP would provide a pair of numbers consisting of maximal service distances 'S' associated with minimum number of facilities to cover so that a cost-effective curve is generated. Population size is not considered in the analysis.

Church and ReVelle take population as an important parameter and develop a model referred as the 'Maximal Covering Location Problem (MCLP)' [13]. The difference between LSCP and MCLP is that LSCP uses maximum service distance concept while MCLP uses maximum populatioin coverage concept. The purpose of the MCLP is to locate a fixed number of facilities in order to maximize the population covered within a service distance 'S', while maintaining mandatory coverage within a distance of T (T>S). The problem is solved using linear programming or heuristic approaches.

A modification of the location set covering problem is proposed by Berlin and Liebman [6]. A dual problem consisting of ambulance location and allocation is considered. For the former problem, the LSCP is used while simulation is employed to solve the latter. The model is written in linear programming format with zero-one values of the variable.

Shuman et al. [73] provide a site selection model for prepaid a group practice plan. The problem is to find the best location(s) for ambulatory care clinics within a metropolitan area such that enrollment in a group practice plan is maximized. This is done by: (1) determining a utilization or enrollment matrix; (2) specifying constraints such as expenditure, clinic enrollment, assignment of each population unit to one clinic location using a heuristic algorithm. The best site is selected. One problem of an heuristic algorithm, however, is finding out how much the near-optimal solution deviates from the optimal solution. The authors have also included a sensitivity model in their analysis.

Daberkow [15], concentrating on the EMS System in a rural northern California environment characterized by seasonal fluctations in population presents a location model to determine the most efficient (least-cost) number and location of ambulance facilities to meet the demand. A mixed integer programming method is used. The model incorporates response and service time standards into the analysis and indicate the trade-off between cost and various time standards. The financial feasibility of individual facility location is also analyzed. Volz [91] introduced a point-to-point driving time model to determine the optimum location of ambulance stations by minimizing average response time to emergency calls for a semi-rural area of Washtenaw County, Michigan. A discrete version of "Steepest Descents" is used to carry out the minimization problem. The structural model presented is relatively complex in nature and may hamper its use. As noted by the author, there exists a local minima which makes it hard to verify with the true optimum.

Grouping a set of points or subregions distributed in a plane into smaller number of major regions according to specified criteria is also another extension of location-allocation problems applicable to emergency services. An example of such a study is that of Bertolazzi, et al. [7] who dealt with the allocation problem of urban EMS of Rome, Italy. The problem was stated as follows:

> Given a region with known spatial distribution of demands for services and given N response units, whose location is also known, how would the region be partioned into areas of primary responsibility (districts) so that the service quality be the best possible? [p. 1]

The purpose of the study was to suggest an approach to the districting problem in terms of optimization of the entire system by considering overall travel time in the region. The resulting solution would then assign a given emergency call from a certain location to an optimal station primarily responsible to that area. Even though the study was made for an urban area, it can as well be applied to EMS systems in either rural or semi-rural environment.

A computerized transportation location model applicable to rural EMS system can be found in the works of Oehrtman [58], and Oehrtman et al. [59]. Local decisionmakers are asked to define appropriate objective(s) to be achieved given their constraints. Two most commonly identified objectives are minimization of maximum response time and minimization of average response time under constraints such as budget limitations, total service demand at each demand location and service capacity of potential locations of EMS facilities. The special algorithm known as Generalized Location Optimization Selection System (GLOSS) is developed to solve multiple origin transportation problems. It is designed to assign demand area to be served by each identified EMS location (origin). The model is versatile. It can be applied in traveling-salesman problem, emergency location problems such as fire department, medical service facilities and optimum location of patrol for police officers. A detailed description of the model will be presented in the next chapter.

Probabilistic Approach to Emergency Medical Services Analysis

The body of literature on location of emergency medical service facilities can be dichotomized into those models that utilize warehouse type or static optimization models or those that incorporate the theory of probability. The typical static optimization models have been sufficiently described in the previous section. Probability models emphasize the randomness of EMS calls. By relating the distribution of EMS calls, patterns of EMS services and other related factors, problems related to the number of calls required in an area, the number of multiple calls during a year while an ambulance is out on duty, and other associated problems can be handled. Queueing models have been used in the recent years for this type of analysis [80].

Bell and Allen [3] use a model that is based on queueing theory to determine the number of ambulances needed to provide specified standards of service. The ambulance fleet is assumed to be based at a single garage. The model assumes a queueing model with unlimiteed number of ambulances. This assumption is critical especially in rural areas where the number of ambulances is usually limited. Along similar lines, Stevenson [76] provides a single ambulance source model to estimate dispatch delay in ambulance service operation. Minimum expected response time is estimated for a given number of ambulances using a queueing model which assumes a Poissonian probability distribution of arriving EMS calls and an exponential distribution of service time. A dual-source system referred to as "primary-secondary system" is also suggested as an alternative. The result was reduced cost at a higher level of service, greater flexibility with respect to changing level of demand and reduced cost at low demand. The model however, doesn't include locational considerations.

Another model that deals with the application of queueing and simulation approach to the problem of urban EMS deployment can be found in Chaiken and Larson [9]. Policies of allocation with respect to size, location and relocation of ambulances are explored in relation to service areas and patterns of patrol. An interested reader is referred to Chaiken's "Probabilistic Models of Fire Company Availability and Dispatching" in the Rand Fire Project [65]. The synopsis presented is applicable to EMS analysis as well. One may also refer to chapters II and III of Beltrami [4] for similar analysis.

Fitzsimmons [24] developed both queueing and simulation models that utilize the idea that the probability of any given unit being busy is dependent upon which of the other units are busy. This is used to predict response time distribution. The model is also used to find the deployment of ambulances that will minimize the mean response time for Los Angeles, Calilfornia. An $M/M/\infty$ queueing model is assumed where EMS arrivals and service times are distributed as Poisson and no waiting is allowed. The travel-distance is based on the rectangular displacement between the X and Y coordinate points of departure and arrival. A valid criticism of this model, and that of Volz's [91] work, is that global optimal solutions cannot be obtained.

An Emergency Cover Model is developed by Groom [30] by combining (1) geographical variables; (2) the distribtion (number, frequency and location) of emergency calls; and (3) organizational considerations. This information is used to calculate (1) the range (defined as the proportion of potential emergencies that can be reached within time period "t" by any one of "r" ambulances) and (2) the availability of service refering to the proportion of time r ambulances are available to respond to EMS calls. The model assumes N dual-purpose equipped and manned vehicles that would handle EMS calls; that is n vehicles will be standing by to handle emergencies and N-n vehicles will be left to serve non-emergencies. When one crew is out for service, the next call is handled by the next one available regardless of the nature of the call (emergency or non-emergency). A queueing model is utilized to determine the proportion of the time there are n, n-1,...,i,...1, 0 vehicles available on standby.

Dearing and Jarvice [18], diverging from the common EMS location service assumptions of deterministic demand and availability of service at any one time, explore the stochastic nature of demand. Their model is a combination of spatial aspects of locating service facilities with service delays caused by the stochastic customer demand. They use zero-one variables in their integer linear programs to see the effects of queueing consideration. The service facilities are assumed to behave in an M/G/1 queueing system.

Swoveland et al. [79] take a different approach by considering a probabilistic branch-and bound procedure to the problem of EMS location. The procedure is used with simulation to obtain a near-optimal ambulance location. Their primary criterion is to locate ambulance depots such that the mean response time is minimized. The problem with such near-optimal solutions is knowing how far off the solution is from the optimum.

Queueing theory has become an important tool in a wide range of emergency service analysis. It can be used to answer probabilistic questions including: (1) the number of EMS crew members required; (2) the number of additional crew members necessary; (3) the average time a customer has to wait to receive a service; (4) the effect of introducing a priority system upon waiting time and (5) the decision problem of relocation of facilities. In this study, it is used to provide information on the probability that an EMS system will be adequate to meet most emergencies.

CHAPTER III

THEORY, METHODS AND PROCEDURES

Emergency medical service systems are being operated as private or public entities. While private operators may be assumed to be attempting to maximize profit subject to their budget constraints, managers of public systems may not have the same profit motive even though they are instructed to manage their system as economically as possible. Given the motives, EMS systems are expected to provide services in an efficient, effective and equitable manner. The efficiency criterion identifies how well scarce resources are used in performing particular services. While effectiveness of a system compares the actual performance against a given standard set by planning authorities, equity refers to the distribution of costs and benefits among the users of the service. With the above criteria in mind, the purpose of this chapter is to present: (1) an overview of the theory of production and consumption of EMS; (2) a summary of methods used to predict the expected number of EMS calls; (3) an outline of the theory and algorithm of the location model that will be used to determine optimum location(s) of EMS facilities; and (4) a summary of the probability model that will be used to predict multiple calls. It is hoped that the theory and methods presented here will aid both public and private operators as they attempt to provide EMS as economically as possible.

An Overview of the Theory of Production and Consumption of EMS

Economists have found it useful to classify goods and services according to their degree of divisibility of consumption for purposes of explanation and prediction of resource allocation and patterns of consumption. The two well recognized classes of goods and services are private and public [69]. All goods and services rated as highly divisible are considered "private" because an individual can simultaneously enjoy the benefits of the product output and exclude others from sharing directly in the consumption of it. On the other end of the spectrum are recognized "public" goods and services that are characterized by a high degree of indivisibility, implying that an individual can consume or benefit from the product output without depleting the availability of it to other members of the society. The problem with such a dichotomy is that it leaves out certain goods and services that have both "private" and "public" characteristics. A case in point is emergency medical services. Its benefits are enjoyed by individuals and at the same time it is recognized as an important element in the general health care system by the public at large. The reduction of the number of premature deaths from an emergency case, the prevention of possible loss of one's productive capacity from an injury and the reduction of the number of possible loss of one's working hours are only a few of the examples that make emergency medical service highly desirable "commodity" by all members of a community or society at large.

Aspects of Demand and Supply of EMS

As with any other market, the theory of demand and supply can be a relevant tool of analysis for a "commodity" such as emergency medical service. The demand side of the market is based on consumers attempting to maximize utility subject to budget constraints or the dual problem of this would be minimization of expenditure given the utility function. In any case, the demand function can be derived using Lagrangian technique. It can be hypothesized that demand for EMS is a function of its own price, given the prices and quantities of other goods and services, personal income and tastes and preferences. If EMS calls are classified as either life-threatening or non-life-threatening, then theory suggests different demand curves. The life-threatening situation is expected to be invariant to price whereas the non-life-threatening is expected to be responsive to price. For this analysis, both types of EMS calls will be considered as one "commodity" characterized by a downward sloping demand curve. Even though it is hard to place value on a life-saving call or the value of preventing an incapacitating injury, it will be assumed that consumers are able to reveal their preferences fully.

Since many people may consume any particular unit of service, vertical summation of individual consumers' willingness and ability to pay for the service is done to arrive at society demand curve or marginal benefit curve [8, 29]. This is shown in Figure 1.

The supply curve is simply the social marginal cost of providing EMS [29]. To serve more emergency cases requires additional facilities and manpower. Assuming no externalities in the production of EMS, the social marginal cost will equal private marginal cost (Figure 1).

If consumers were to pay the full cost of EMS, as in the case of private provider, Xp units would be served. The cost of EMS for each consumer in the private system would be C_2. Since the benefits of EMS enjoyed by individuals are externalities which benefit the society as a whole, social marginal benefits are higher than private marginal benefits. From society point of view, the service level at Xp implies benefits that will be gained by society, which is C_4 while the cost is only C_2. The implication of this is that there is an underinvestment in EMS. This arguement will be the point of departure for building up a case for production subsidy.

The optimal level of social welfare can be achieved when social marginal cost is equal to social marginal benefits [89]. Referring to Figure 2, this point is shown where service level is at X_s, and price per unit is C_3. Since the private consumer is only willing to pay C_1, the difference between C_3 and C_1 must be paid by the government in the form of subsidy. So the total cost of serving the optimal level of service is divided between the private cost to the consumer which is C_1, and the social cost of $C_3 - C_1$. The effect

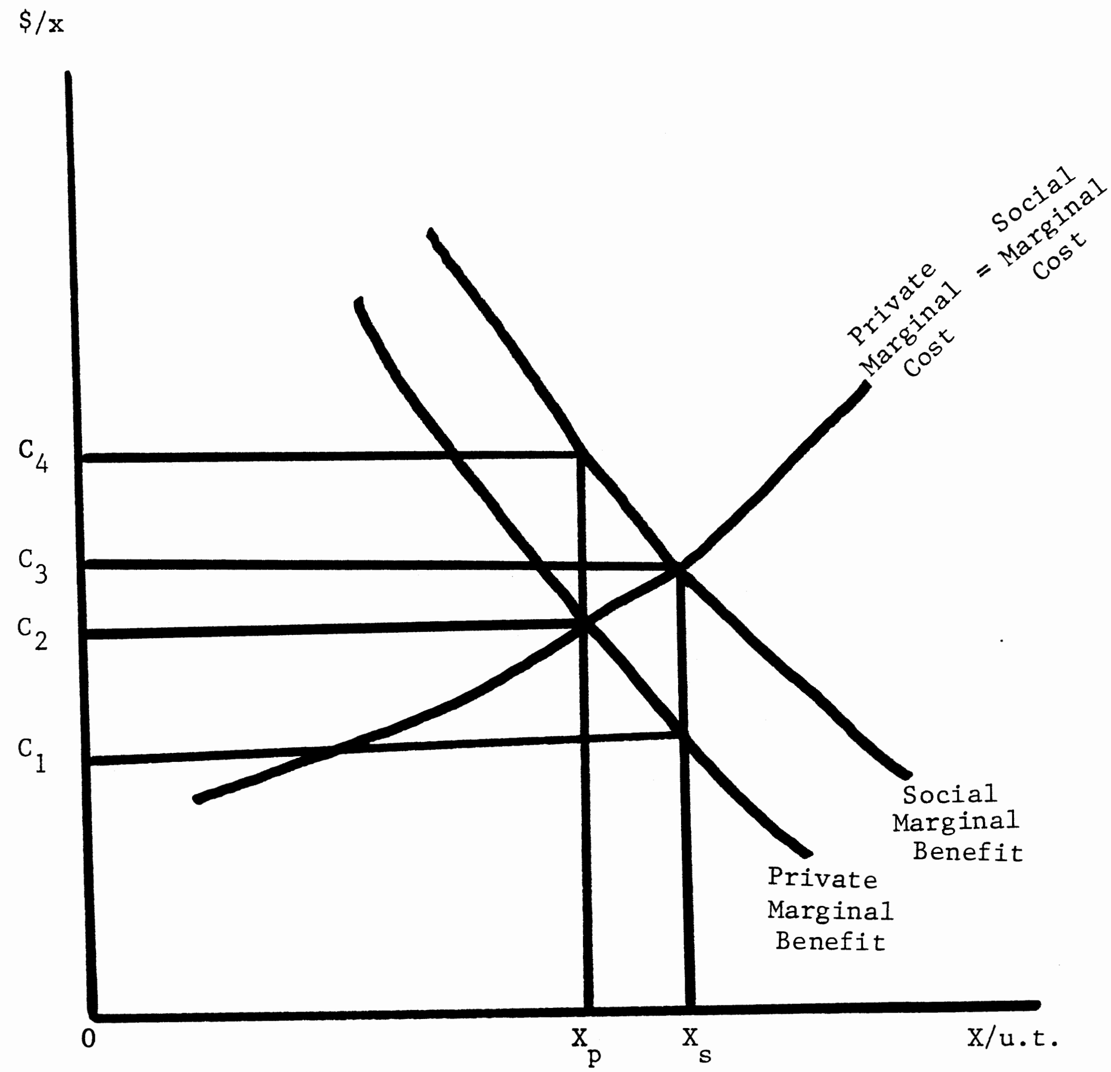

Figure 1. The Market for EMS Without Government Subsidy

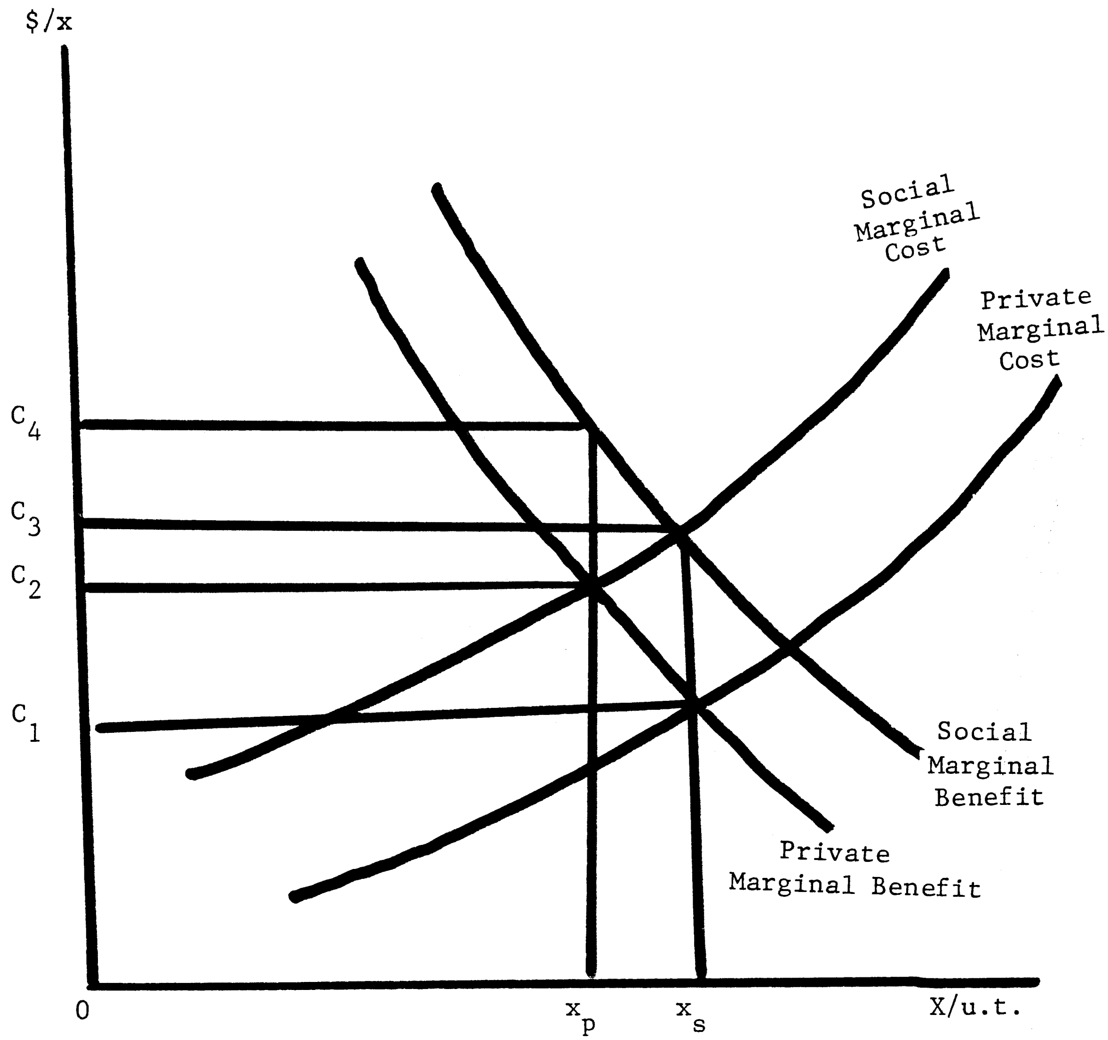

Figure 2. The Market for EMS With Government Subsidy

of this subsidy is to lower the private marginal cost by the amount of the subsidy such that at service level X_s, the social marginal cost and social marginal benefit are equal and also the private marginal cost and benefits are equal.

For empirical analysis of demand for and supply of EMS, appropriate data are rare, However, utilization analysis is made by using population and age distribution of population to derive and predict "need" for emergency medical services in the State of Oklahoma.

Estimating Current and Future Area Population

The size and distribution of population plays an important role in estimating total EMS calls. Several alternative ways of projecting area population are available. For example, polynomial or exponential curves that take into account the size of population at a base year and the number of years from base year to forecast year can be used [72]. Sometimes simple or multiple regression models are employed to incorporate population as a dependent variable and one or more independent variables consisting of such factors as per capita income, sales tax, and motor vehicle registration. If population is used to predict EMS calls, a relatively accurate method of projecting population is important.

The Department of Agricultural Economics, Extension Division, Oklahoma State University has developed a computer program to predict population of a given area in the State of Oklahoma over the next twenty-five years [36].

The model is based on initial population, birth rate, death rate and net migration. It takes into account all age-sex cohorts, age-sex specific fertility rates, age-sex specific mortality rates and net migration rates. The age-sex specific population has 12 cohorts consisting of:

1.	Less than 15 years of age
2.	15-19
3.	20-29
4.	30-39
5.	40-44
6.	45-49
7.	50-54
8.	55-59
9.	60-64
10.	65-69
11.	70-79
12.	Over 79

The basic model that generates the projected population is based on the following mathematical formulation:

$$TOT.POP_k = \sum_{i=1}^{12} \sum_{j=1}^{2} P_{ijk} \qquad \text{Equation (3.1)}$$

where $TOT.POP_k$ = Total population in time period k;

P_{ijk} = Population in time period k, cohort i, sex j.

Given that $P_{i,j,0}$ is the initial population on choort i, sex j,

$$P_{i,j,k} = P_{i,j,k-1} + ADV.P_{i-1,j,k-1} + M_{i,j,k-1} - ADV.P_{i,j,k-1} - D_{i,j,k-1} \qquad \text{Equation (3.2)}$$

where $ADV.P_{i,j,k}$ = Advancement from cohort i to cohort i+1 between years k and k+1;

$M_{i,j,k}$ = Net Migration into cohort i between years k and k+1; and

$D_{i,j,k}$ = Deaths by members ofcohort i, sex j in years k and k+1.

The number of births of sex j in year k is expressed by

$$ADV.P_{0,j,k} = \sum_{i=1}^{12} b_i P_{i2,k} \qquad \text{Equation (3.3)}$$

where b_i = the rate of birth for women in cohort i.

The number of deaths in time period k, cohort i, sex j is given by

$$D_{i,j,k} = D_{i,j,0} T_{i,j} P_{i,j,k} \qquad \text{Equation (3.4)}$$

where $D_{i,j,0}$ = the initial death rate for cohort i, sex j; and

$T_{i,j}$ = trend in death rate for cohort i, sex j.

For further clarification, the interested reader is referred to Hamilton et al. [37] and Shryock [72].

Data for initial population by age and sex were obtained from the 1970 census of population [84]. For birth rates, death rates and trend the computer model uses data from the Oklahoma State Department of Health.

Net migration is one of the most sensitive part of the model. Conceptually, it is the difference between the total in-migration and out-migration of individuals and/or families into or out of a particular location. Migration is mainly influenced by several factors concerning the relative attractiveness of a community based on economic and non-economic reasons. Even though the final decision to move may be based on weights such as net benefit-cost ratio of moving, behavioral decisions such as this are very hard to predict especially when annual data are not available. However, the Census Bureau provides periodic data such as that of 1960-1970 and the period between April 1, 1970 and July 1, 1978. An average of annual rate were derived from these two periods as an initial rate to be used in the computer program. This rate was then adjusted to reflect the total population of 1980.

Local decisionmakers and planners usually find EMS planning incomplete without considering an estimate of current and future needs for services. Estimating of the number of EMS calls is a basic element in the preparation of feasibility studies for new EMS entrants, and is also important in the preparation and analysis of budgets of existing EMS firms. Moreover, it is an important datum for optimal location analysis.

Estimating Current and Future Emergency Medical Service Calls

Defining Emergency Medical Service Calls and Service Area

According to the Emergency Medical Services Improvement Act [21] emergency medical service is defined as

> ...the transportation of and immediate medical care provided to an emergency patient prior to his arrival at a medical facility. Emergency medical services include all services rendered to the emergency patient to prevent loss of life or aggravation of physiological or psychological illness or injury [p. 46].

Inspection of an EMS operator's records indicate that incidents requiring the use of ambulances include: trauma, acute cardiac arrest, burns, poisonings, spinal injuries, neonatal care, psychiatric and other emergency situations. In estimating total EMS calls, similar categories are used by both Deems [19] and Kvalseth and Deems [48]. They consider demand arising from drug intoxication, obstetrics or gynecology, auto trauma, cardiovascular, other illness and dry runs. The models used by Aldric et al. [1], Waller et al. [93] have similar classifications. Daberkew and King [16] classify calls into: (1) accidents and (2) accute illness. They view EMS demand as demand for emergency room service and demand for ambulance services.

In this study, realized demand for emergency medical services is conceived to be the total number of calls for service received by an EMS operator service at a specified period of time. A "run" is a response made by EMS crew to the location of the caller to render the service required. There are cases of "dry runs" whereby the crew was unable to deliver the service after the trip was made. The reason could be that the emergency was taken care of by some other means.

Doeksen et al. [21] classified EMS calls into three general categories. The first category deals with cases of highway accidents; i.e fatalities and incapacitating injuries on county roads, city streets and/or highways. The second category involves calls related to other medical services such as strokes, heart attacks, home accidents and the like. This category includes EMS calls arising from nursing home transfer services. The third category deals with transfer calls to move patients from one hospital to another. In this analysis the number of hospital-to-hospital transfer calls are not included in the total demand estimation. These calls are dependent upon the size and service capacity of local hospitals, medical staff, and other factors such as medical situations and personnel making it difficult to project current and future calls of this type. Therefore this analysis addresses the sum of all highway accident and other medical services including nursing home transfer calls.

The study area was first divided into service demand areas following township lines of each county. Each area is approximately 36 square miles. This was done for the purpose of exactly locating the origins of calls. It also served as a guide for observing temporal and spatial distribution of calls so that adjustments concerning addition of new facilities or possible relocation decisions could be made. Moreover, the distribution of calls is used for the purpose of optimum facility location in the chapter IV.

It is proposed that calls generated from highway accidents can be determined by using the size of local the population [20, 21]. Here, distinction is not made as to whether the emergency caller is out of state or out of the local community. In estimating highway accidents, an initial attempt was made to include explanatory variables such as the number of vehicles registered the type of road, time of the day, day of the week, weather conditions and/or traffic conditions. Preliminary regression analysis of highway accidents as a function of vehicles registered and also tax receipts of gasoline consumption by each county was conducted and were not better estimators when compared with population variable as a independent variable. Moreover, after considering factors such as data requirements for current and future projections, population size of the local community was selected to be the sole determinant of highway accident calls.

Secondly, it is proposed that other medical calls and nursing home transfers can be determined by considering the distribution of population by age. Analysis of several EMS operators' records show that both other medical and nursing home transfer calls are an increasing function of age [20, 21]. Utilization rates are derived using age specific cohorts for the population of every county. For those counties without age-specific data, current utilization rates developed by Doeksen et al [21] are used. The rates developed are based on a cross-section study and consist of a sample size of about 25 percent of the total population of the study area.

Estimating the Number of Highway Accidents

Utilization rates per 1000 population for all highway accidents calls were derived for every county in the study area using the following sources of data: (1) records submitted to Oklahoma State University's Agricultural Economics Department, and (2) data collected by the Oklahoma State Highway Safety Department.

The expected number of highway accident calls in time period t is given by

$$Y_1 = u_i P_t \qquad \text{Equation (3.5)}$$

where P_t = Expected size of population of the area in time t

u_i = Utilization rate for highway accident calls per 1000 population

It follows that

$$u_i = \frac{Y_1}{P_t}\ (1000) \qquad \text{Equation (3.5a)}$$

For those EMS systems whose records were not available, data were obtained from the office of the State Highway Safety Department. Records are aggregated for four years from October 1, 1976 to September 30, 1980. A simple average was taken as a basis of calculating the required annual utilization rates. On the average, data obtained from EMS operators were not much different from the ones received from the office of the State Highway Safety records. The slight difference could have been due to EMS operators' failure to indicate the call as a highway accident and/or some highway accident victims could have used other means of transportation especially in remote areas that require long response time.

Estimating Other Medical and Nursing Home Transfer Service Calls

As was postulated earlier, the expected number of other medical and nursing home transfer service calls is a function of size of population by age group. The population program displays projections for nine age groups, even though the input requires 12 group agedata. The age components are summarized into less than 20, 20 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 64, 65 to 69, 70 to 79 and lastly 80 and over. Therefore, annual utilization rates will be determined based on the nine age cohorts. The number of calls for each age composition is given by

$$Y_{21} = u_{21} P_{1t}$$

$$Y_{22} = u_{22} P_{2t}$$

$$\vdots \qquad \vdots$$

$$Y_{2i} = u_{2i} P_{it}$$

$$\vdots \qquad \vdots$$

$$Y_{29} = u_{29} P_{9t}$$

The total expected number of other emergency medical calls is thus

$$\sum_{i=1}^{9} Y_{2i} = \sum_{i=1}^{9} U_{2i} P_{it} \qquad \text{Equation (3.6)}$$

Where Y_{2i} = Expected number of other medical and nursing home transfer service calls in age group i where i = 1,2,...,9.

P_{it} = Expected size of population in age group i, time period t.

It follows that the utilization rate for each age group is given by

$$u_{2i} = \frac{Y_{2i}}{P_{it}} (1000) \qquad \text{Equation (3.6a)}$$

Required data were obtained from two sources. The first source is the records of EMS operators whenever available. For those services where data is not available, an alternative source is the utilization rate reported by Doeksen et al. [21].

Total Number of Emergency Medical Service Calls

The total expected number of EMS calls is the sum of the calls arising from highway accidents and all other calls due to other medical and nursing home transfer calls, i.e.

$$Y_T = Y_1 + \sum_{i=1}^{9} Y_{2i} \qquad \text{Equation (3.7)}$$

Where Y_T = total EMS calls and Y_1 and Y_{2i} are as defined earlier.

Optimum Facility Location Model for EMS Systems

In this section, an optimal location model is developed to describe the theoretical linear programming model that will be applied to determine the optimal location(s) of either single or multiple EMS system(s) under alternative objectives with certain restrictions. It is a static optimization model implying that it does not consider the dynamic nature of EMS. The interested reader who wants detailed treatment of this model is referred to such alternative sources as Heady and Candler, Goodard and, Oehrtman [34, 28, 58].

After determining the optimum location of service(s), one can estimate quality of service variables such as maximum response time and/or average response time can be obtained. The cost associated with alternative number of locations against the quality of service variables can be weighted to evaluate differences in quality and cost for various numbers of EMS facilities. This is very important especially in providing a guide to those concerned with such practical problems during the process of decisionmaking.

The General Transportation Model

One of the special classes of linear programming problems is the classical or sometimes known as the Hitchcock-Koopmans transportation problem. The model was first developed to serve as a tool in finding the minimum-cost strategy of shipping a homogeneous product from a number of supply origins (sources of supply) to a number of demand locations (destinations). The optimal solution is determined through a series of repetitions of a single standard procedure referred to as an "iterative" procedure. Even though the model was used or associated with "Shipping" a product, it is also applicable to location problems related to EMS facilities, fire departments and/or police patrol problems [88].

The transportation procedure presented below is an efficient algorithm that will provide the policymaker with optimum location(s) and quality of service indicators such as average response time and maximum response time for various numbers of facilities given alternative objectives and restraints. The objective of the model is to find the values of a decision variable, X_{ij}, that will minimize a linear objective function f(X), subject to specific linear constraints.

The mathematical structure of the model is presented as follows:

$$\text{Min } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$$ Equation (3.8)

Subject to the constraints

$$X_{ij} = a_i \text{ where } i = 1,2,\ldots m$$ Equation (3.9)

$$X_{ij} = b_j \text{ where } j = 1,2,\ldots n$$ Equation (3.10)

$$X_{ij} \geq 0$$ Equation (3.11)

$$\sum_{i=1}^{m} a_i = \sum_{i=1}^{n} b_j$$ Equation (3.12)

where

m = number of possible locations of EMS (supply areas)

n = number of locations of EMS users (demand areas)

a_i = EMS capacity at the i^{th} EMS supply loction

b_j = amount of EMS demanded by the jth location of EMS users

X_{ij} = amount of EMS to be supplied by the facility at location i to EMS users at location j.

C_{ij} = per unit "cost" of supplying EMS from EMS facility location i to each user location j. As a proxy for "cost", a one way road mileage is used.

$C_{ij}X_{ij}$ = Total cost of supplying X_{ij} units of EMS from EMS facility location i to any user at location j

According to the above model, we have n constraints on supply, and m constraints on demand. There are also m+n equations in m X n unknown variables (X_{ij}'s). This means there are (m+n-1) independent restrictive equations and the basic solution will contain (m+n-1) nonzero variables. The transportation problem can be summarized in a framework known as the transportation tableau shown in Figure 2.

j / i Source	Location of Demand Areas 1	2	. . .	j	. . .	n	Dummy Supply	a_i
1	C_{11} X_{11}	C_{12} X_{12}	. . .	C_{1j} X_{1j}	. . .	C_{1n} X_{1n}		a_1
2	C_{21} X_{21}	C_{22} X_{22}	. . .	C_{2j} X_{2j}	. . .	C_{2n} X_{2n}		a_2
⋮			. . .		. . .			⋮
i	C_{i1} X_{i1}	C_{i2} X_{i2}	. . .	C_{ij} X_{ij}	. . .	C_{in} X_{in}		a_i
⋮								⋮
m	C_{m1} X_{m1}	C_{m2} X_{m2}	. . .	C_{mj} X_{mj}	. . .	C_{mn} X_{mn}		a_m
b_j	b_1	b_2	. . .	b_j	. . .	b_n	Total b_i	Total a_i

Figure 3. Tableau Format of the Transportation Model

Assumptions

Certain assumptions must be satisfied before the transportation procedure can be used to solve either transportation problems or other kinds of problems. These assumptions are:

1. the services being provided by each of the various facility locations origins are homogeneous (i.e., availability of services at each origin will equally satisfy the demand in any service user location--equation 3.9);
2. the service capacities at various origins and demands of various locations of service users are known, and total demand must equal total capacity--equation 3.12. (When discrepancies occur between service capacity and user demand, a dummy service capacity or user demand vector is used to produce equality; this dummy vector is used to signify unused capacities or unsatisfied demands);
3. the costs of providing services by any one origin to other locations of service users are known, and are independent of the amount of services provided i.e., there is a constant per unit cost of service provided between locations;
4. there is an objective function to be minimized-- equation 3.8; and
5. The decision variables, X_{ij}'s, cannot be executed at negative levels---equation 3.11.

Specification of Alternative Objectives

For practical optimum location analysis, the transportation model can be used to achieve several alternative objectives. It is usually desired that EMS crew be at the scene of the victim's location as quickly as possible so that the patient can be stabilized. However, EMS providers have certain constraints such as budget, total service demand and service capacity. Under such restrictions, the two most commonly identified objectives are:

1. Minimize the maximum response time to reach an emergency; and
2. Minimize the average response time to reach an emergency.

Under the first objective, the value of b_j in equation 3.10 is set to unity for all demand locations $j=1,2,...,n$. The optimum location(s) is (are) then determined by choosing the smallest maximum distance travelled from a supply origin to a source of demand. If the second objective is to be considered as a criterion, the values of b_j are set to the expected number of EMS calls coming from all sources of demand $j = 1,2,...,n$. Here, the optimum location(s) is (are) determined by choosing the smallest value of the objective function.

Data Requirements

The stucture of the mathematical model presented to determine the optimum location(s) requires the following set of data.

1. identification of supply points;
2. identification of demand points;
3. specification of the demand requirements;
4. specification of available supply; and
5. determination of a cost matrix.

The first set of data is simply the number of EMS providers currently existing or some potential location either for basic ambulance, advanced life support or first responder systems. The number of supply origins are identified by the letter i = 1, 2, 3, ...,m.

The second set of data is the number of demand points or sources of demand. In this study, unit of demand location is arbitrarily defined to be an area bounded by a township line of each county. This is approximately a 36 square mile area (6 miles X 6 miles). Every county was delineated according to the above configuration and is identified by the number j= 1, 2, 3, ..., n. A total of 2046 demand areas were identified for the statewide study discussed in Chapter V.

The third data requirement is the total demand arising from each demand location. The toal demand for EMS was defined earlier to be the sum total of all fatalities and incapacitating injuries from highway accidents and all other medical calls related to heart attack, stroke, and other acute illnesses including nursing home transfer calls. The task of determining the distribution of demand was performed in three steps: (1) counts of the number of houses or residential dwellings in each county by township was made using the housing inventory record of the most current General Highway Map prepared by the Oklahoma Department of Transportation Planning Division; (2) the number of residential dwellings was multiplied by the average nmber of family members per household to get the distribution of population by township or demand area; and (3) the number of calls by each demand area was determined according to population distribtion of each township. The results indicate that the number of calls diminish as the demand area gets further and further away from a city or a town.

The fourth set of data specifies available supply. According to the assumption, the services being provided by each of the various facility locations origins are homogeneous. This means, that the availability of services at each origin will equally satisfy the demands in any of the demand location.

The fifth and final data requirement is cost. It was assumed earlier that the costs of providing services by any one supply origin to any one of the demand locations are known and are independent of the amount of services provided. One of the most important measures of effectiveness of an EMS system is travel time or response time. Therefore, our "cost" of supplying one unit of ambulance service from ambulance facility location i to each user location j is a one way mileage. This distance is determined using detailed road map obtained from the Oklahoma Department of Transportation Planning Division. Road mileage was obtained using one or some combination thereof: (1) Interstate Highway route; (2) State Numbered Highways; (3) U.S. Numbered Highways; (4) Gravel Road; and (5) Paved Road.

While determining the mileage matrix, it was assumed that EMS operators take the shortest possible distance necessary to reach an emergency. It is also assumed that each value of the C_{ij} can be used as a surogate of travel time. On the average, an ambulance is assumed to respond at a speed of one mile per minute.

Some demand locations have long response times because of natural barriers such as lakes and rivers and there are those located in remote areas without any road to link them to an ambulance facility. If the distance from an EMS location to a user location is more than 50 miles, an artificially large number such as 9999.99 was assigned because a response time of 50 minutes to an emergency case is considered unsatisfactory.

There are two types of EMS delivery that need to be mentioned. The transportation system could be open or closed. If a dispatch is made to a demand area and the operator does find it necessary to re-route his return to the station, then it is called an open system. However, if a dispatch is made to the scene and the operator comes back to his station without re-routing, then the system is known as a closed system. The constraint equations specified in the model will not change. However, the cost component, C_{ij}'s in the objective function will be different. In the closed system the C_{ij}'s are defined as one-way road mileage (proxy for response time) from an origin to a demand point. If the system is open, some modifications are needed, depending on the objective function. There are two ways of handling the situation. If the objective is to minimize the maximum response time, then the system is treated like a closed system because location decision depends on the time traveled from an origin to a destination, and the values of b_j's in equation 3.10 are all set to unity. To date there is insufficient data established on the patterns of EMS deliveries. For such reason, the problem is handled here as if it were a closed system. The justification of this decision stems from the fact that our objective is to determine the location of origin.

The Procedure

The Generalized Location Optimization Selection System (GLOSS) will be used to solve the location problem [59]. It is an efficient algorithm based on the general linear programming transportation procedure presented earlier. The system can be used to calculate optimum solution for all combinations of multiple origin transportation problem. It is designed in such a way that slack destination is added whenever supply is greater than demand and a slack origin is added when available supply is less than demand. This is required because of the assumption made earlier that the total supply must equal total demand. The capability of the algorithm was also expanded to calculate optimum solutions for all combinations of multiple origin transportation problems by using the iterative-expansion procedure.

An interative-expansion procedure [59] is a process of determining the optimal solution through a series of repetitions of a single standard procedure. This entails a complete enumeration of all possible combinations of EMS locations. For example, let us consider a case where there are five alternative cities or towns where EMS facilities could be built. The community may not afford to invest in all locations. The problem is geared to determine the best location of the first EMS location, then two, three, four or five depending on how much they want to spend. The interactive procedure uses combination formulas to arrive at the number of possible combinations and the costs associated with each. The formula is given by:

$$_mC_r = \binom{m}{r} = \frac{m!}{r!(m-r)!} \qquad \text{Equation (3.13)}$$

where m = the number of origins

c = the number of combinations or subsets

r = the number of times m is taken.

For illustration of the formula, with one ambulance to be located at any one of the five supply points there are a total of five possible combinations, i.e.,

$$_5C_1 = \frac{5!}{1!(5-1)!} = 5 \text{ combinations;}$$

and with two ambulances: $_5C_2 = \frac{5!}{2!(5-2)!} = 10$ combinations.

Similar calculations can be made for three, four or any number of combinations. Further clarification can be made in relation to the above calculations. For instance, the combination of five communities each taken three at a time yields ten possible combinations of three communities that would serve as supply origins for the EMS system. Then the combination with the least-cost is picked as the best alternative.

The transportation procedure, GLOSS, was used to assign the demand areas to an origin of supply (EMS) in such a way that total cost is minimized. After solving the allocation problem, the system was used to estimate certain effectiveness criteria such as maximum response time and average response time. Maximum area coverage is ensured by solving for the maximum response time. The average response time criterion is used to measure effectiveness since it involves the shortest time period required to reach an emergency scene.

After determining optimal location(s), budget analysis is essential for ensuring cost effectiveness of EMS systems. This analysis is presented in Chapter IV.

Probabilistic Aspects of EMS Delivery System

Emergency medical calls are assumed to be received at random by an Emergency Medical Service (EMS) System. Immediate response cannot always be guaranteed due to the magnitude and distribution of these calls by time of day and the variation in time to complete a service once a call is received. Service time depends on the nature of the call, type and condition of the road to be driven over, or time of day. Planning for a community EMS could have been made easier if some questions about the number and nature of calls received at different time periods could be answered.

The purpose of this section is to develop a method that may be used by community leaders to answer questions concerning the probability and the expected number of various types of calls that will be received by their local EMS. Of particular interest will be the calls that arrive while an emergency vehicle is answering an earlier call. Due to the stochastic nature of EMS demand and its service times, a queueing model is proposed to determine the probability and magnitude of the expected number of calls.

System Description

A call for an EMS is made when a highway accident involving injury occurs, a person has a heart attack or stroke, or a nursing home transfer service is needed at a given time and location. This call will be considered as one unit of EMS demand per unit time. Service starts as soon as the ambulance is dispatched to the location of the caller. Service ends when the customer is fully attended and the crew is ready to handle another call. The detailed procedure of EMS response involves the following important steps.

1. receiving the call for service;
2. preparation for dispatch;
3. dispatch to the scene;
4. arrival at the scene and evaluation of the vistim's conditions;
5. stabilizing the victim when necessary. This may be handled by first responders and is critical to helping victims until an ambulance arrives;
6. departure from the scene to patient's destination. This could be a clinic, hospital or nursing home for example;
7. travel from patients destination back to EMS station.

Service is said to be ready for another call at this stage. The operator's records often indicate that service time and service rate (the number of services completed per hour) vary depending on the nature of the call and time of day. Services related to non-emergencies, such as nursing home transfers, take longer than services related to emergencies. Response times to patient's location are much less than the time taken to travel to patient's destination.

The Theoretical Model

An EMS system can be described and analyzed by considering the rate and pattern of calls it receives, the rate and distribution of service time and the number of crew available at a given time period. A queueing model known as M/M/S may be applied, where the first M refers to arrival pattern of customers (Markovian or Poisson), the second M refers to service time distribtion which is assumed to be negative exponential and the letter "S" refers to the number of servers (EMS crew) available.

Many EMS studies that involve a probabilistic analysis deal with a model in which it is assumed that there are an infinite number of crew available for service. This is usually appropriate for urban EMS system with a large fleet of ambulances. In a rural environment, however, only one EMS crew typically a large area such as a county. Therefore, "S" in this study is equal to one.

In reviewing the nature of EMS operators in rural areas, the M/M/1 queueing model may best address the purpose of this study. It's use will determine the number of multiple calls while the crew is out and also address other probabilistic questions, such as: (1) the probability of busy period; (2) the average waiting time for a customer before an EMS crew arrives at the demand location; and (3) the average waiting time in the system.

In a Poisson Process, a sequence of discrete events (EMS calls) characterized by a single parameter (λ= average rate of EMS calls) occur such that in a sufficiently short time interval length T, the probability of exactly one event occurring is approximately T, the probability of two or more events is negligible, and the occurrence of an event in one interval has no influence on the occurence of events in other nonoverlapping intervals. The events in such a process are said to occur at random. For more clarification one may refer to Gross and Kleinrock [43].

It follows that the probability of n calls is given by

$$P(n,T) = \frac{(\lambda T)e^{-\lambda t}}{n!}, \quad n= 0,1,2,... \qquad \text{Equation (3.14)}$$

The mean and variance is λ. One condition that must be fulfilled is that the interarrival time (the time interval between two successive calls in a queueing system) has a negative exponential density function expressed by

$$A(t,T) = \lambda e^{-\lambda T} \qquad \text{Equation (3.15)}$$

where λ and T are as defined above and

e = natural constant = 2.71828

The mean and variance of the above function can be derived to be $\frac{1}{\lambda}$ and $\frac{1}{\lambda 2}$ respectively.

The second important assumption deals with service time distribution. This is also assumed to have negative exponential distribtion respresented by

$$S(T) = \mu e^{-\mu T} \qquad \text{Equation (3.16)}$$

Where e and T are as defined earlier

and μ = service rate.

The mean service time can be derived to be $\frac{1}{\mu}$.

It is also assumed that EMS calls are served on the basis of first-come, first-served basis.

The reasonableness of these assumptions can be checked either by a chi-square goodness-of-fit test of a given data set or by inspection of preliminary data from EMS operators. It was on the basis of the latter that the assumptions were made. The observed distributions may not be exact as described in the theoretical model. The results, however, will not be seriously affected [65].

Given a sufficiently short time interval, T, any EMS system is in a state where there may be one call, no call, one service and no service scenario. The probabilities of each are given by

1. probability of exactly one call during T = $\lambda_n T$
2. probability of no call during T = $1 - \lambda_n T$
3. probability of exactly one service during T = $\lambda_n T$
4. probability of no service during T = $1 - \mu_n T$

Multiple events of arrival and services during the short time period T, are assumed to be zero. Hence

$$Pn(t+T) = P_n(t)\,[1-\lambda_n T][1-\mu_n T] + P_{n-1}(t)[\lambda_{n-1} T][1-\mu_{n-1}(t)] + P_{n+1}(t)[\mu_{n+1} T][1-\lambda_{n+1} T] \quad \text{Equation (3.17)}$$

In Chapman-Kolmogorove dynamics [92], the probability of n units in the system at (t+T) is the sum of the probabilities of the following mutually exclusive and collectively exhaustive events:

a) n units in the system at time t and no arrival or service completed during T;

b) n-1 units in the system at time t and we had one arrival and no service completed during T; and

c) n+1 units in the system at time t, no arrival and one service completed during T

From equation 3.16, for $n \geq 1$

$$\frac{dP_n(t)}{dt} = - P_n(t)\ [\lambda_n + \mu_n] + P_{n-1}(t)[\lambda_{n-1}] + P_{n+1}(t)\ [\mu_{n+1}]$$ Equation (3.18)

For n=o

$$\frac{dP_o(t)}{dt} = \lambda_o P_o(t) + \mu_1 P_1(t)$$ Equation (3.19)

Assuming that

$$\lim_{t \to \infty} P_n(t) = P_n$$ exists and

$$\lim_{t \to \infty} \frac{dP_n(t)}{dt} = 0$$

Then for n>0

$$0 = - (\lambda_n + \mu_n)\ P_n + \mu_{n-1}\ P_{n-1} = \lambda_{n-1}\ P_{n-1}$$ Equation (3.20)

and for n = 0

$$0 = -\lambda_o P_o + \mu_1 P_1$$ Equation (3.21)

For an M/M/1 Model, equations 3.20 and 3.21 can be used to derive the probability for n calls in the system. By letting ρ be the ratio $\frac{\lambda}{\mu}$, the probability of m EMS calls can be derived to be

$$P_n = (1-\rho)\rho^n,\ 0 \leq P \leq 1$$ Equation (3.22)

The following important operating characteristics can be obtained from the system of equations described above.

The average number of calls in the system is represented by

$$L = \frac{\rho}{1-\rho}$$ Equation (3.23)

with variance

$$\sigma_n^2 = \frac{\rho}{(1-\rho)^2}$$ Equation (3.24)

The average time spent in the system is

$$W = \frac{L}{\lambda}$$ Equation (3.25)

The average number of units in a queue is given by

$$Lq = \frac{\rho^2}{1-\rho}$$ Equation (3.26)

and the probability of n 2 in the system for example, is given by

$$\rho^2$$ Equation (3.27)

The average time an emergency unit spends waiting in queue is

$$Wq = \frac{\rho}{(1-\rho)\mu}$$ Equation (3.28)

The probability of having to wait or the probability of a busy period for the crew is

$$\rho = \frac{\lambda}{\mu}$$ Equation (3.29)

The probability that a caller will not have to wait or the probability of an immediate response is

$$1-\rho$$ Equation (3.30)

The above results will be applied to a single EMS crew system in Marshal County, Madill, Oklahoma, in chapter IV.

So far we have dealt with a single EMS model. However, the model will no longer apply for more than one service. Letting S = the number of ambulance, Po = Probability of no calls, P_n = the probability of "n" calls, the intensity of demand or utilization factor is defined by

$\rho = \frac{\lambda}{s\mu}$ for an M/M/S queueing Model.

The probability of no calls is given by

$$P_o = \{[\sum_{n=o}^{s-1} \frac{(s\rho)^n}{n!}] + [\frac{(s\rho)}{s!(1-P}]\}^{-1}$$ Equation (3.31)

The probability of "n" calls where "n" is between zero and s is

$$P_n = \frac{(s\rho)^n P_o}{n!}$$ Equation (3.32)

The probability of "n" calls where "n" is greater than or equal to s is

$$P_n = \frac{(S^S \rho^n) \, P_o}{S!} \qquad \text{Equation (3.33)}$$

The average number of callers waiting for service is determined by

$$Lq = \frac{(S\rho)^{S+1}}{(S-1)! \, (S-S\rho)^2} P_o \qquad \text{Equation (3.34)}$$

The average number of callers waiting for service with EMS crew numbers of 1, 2, 3, can be derived from the above identity to be

$$Lq = \frac{\rho^2}{1-\rho} \quad \text{for } S = 1 \qquad \text{Equation (3.34a)}$$

$$Lq = \frac{2\rho^3}{(1-\rho)\,(1+\rho)} \quad \text{for } S = 2 \qquad \text{Equation (3.34b)}$$

$$Lq = \frac{9\rho^4}{2+6\rho+7\rho^2+3\rho^3} \quad \text{for } S = 3 \qquad \text{Equation (3.34c)}$$

It can be seen at the outset that the calculation can get tedious as the number of servers increase. However, charts can be used to get approximate values of the relevant operating characteristics.

CHAPTER IV

APPLICATION OF THE MODELS TO LOCAL COUNTY

This chapter is designed to illustrate the use of the economic tools developed in Chapter III for county level decisionmakers. The population model, the determination of the expected number of EMS calls and the probability model are applied to Marshall county. Logan County is used to demonstrate the optimum location model and budget analysis.

The Population Model as Applied to Marshall County

Estimates of Current and Future Population

County and community leaders in Marshal County contacted the State Health Department and Cooperative Extension Service in early 1981 for an analysis of their EMS system. As part of the analysis, projection of population of the county was considered to be essential. The details of the model is explained in Chapter III. A central component of population model is the migration rate. In Marshal County, the migration rate for 1980-1990 is assumed the same as that which occurred from 1970-1980.

The model projected that population would increase from 10,495 in 1980 to 14,660 in 1990 (Table I).

Estimates of Current and Future EMS Calls in Marshall County

Annual utilization rates of EMS service derived from 1980 Marshall county EMS data are presented in Table II. These rates indicate the number of EMS calls generated per year for each one thousand people in each age group.

Using the population projections and the utilization rates, the number of calls by year and by age group is projected. The number of calls is expected to increase from 698 in 1980 to 978 in 1990 (Table III).

The Location Model as Applied to Logan County EMS System

When EMS systems are organized, it is imperative that first responder systems and ambulances be located to give the best service at least cost. A model was devised to derive the optimum location of first responders and vehicles. The data requirements include: (1) dividing the service area into demand areas and estimates of the number of calls

TABLE I

PROJECTED POPULATION OF MARSHALL COUNTY
OKLAHOMA, BY AGE, 1980-1990

AGE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Under 20	2921	3003	3089	3179	3275	3375	3480	3590	3705	3825	3950
20-29	1372	1439	1505	1570	1636	1702	1768	1835	1904	1973	2044
30-39	1122	1189	1257	1327	1400	1474	1550	1628	1708	1790	1873
40-49	1023	1070	1119	1174	1232	1295	1362	1433	1508	1586	1668
50-59	1141	1156	1173	1193	1217	1246	1278	1316	1358	1405	1458
60-64	649	653	657	662	667	673	680	689	698	710	723
65-69	657	663	669	674	680	686	692	699	706	714	723
70-79	941	964	986	1008	1028	1049	1068	1088	1107	1127	1146
Over 80	667	707	747	787	827	867	908	949	990	1032	1075
Total	10495	10844	11202	11574	11962	12366	12788	13227	13684	14162	14660

TABLE II

UTILIZATION RATE OF OTHER MEDICAL CALLS AND NURSING HOME TRANSFERS PER THOUSAND POPULATION MARSHALL COUNTY, OKLAHOMA, 1980

AGE	CALLS PER THOUSAND
Under 20	9.24
20-29	16.76
30-39	8.02
40-49	14.66
50-59	29.80
60-64	52.39
65-69	36.53
70-79	117.96
Over 80	287.86
Total	573.22

Source: [21]

TABLE III

ANNUAL PROJECTED EMS CALLS FOR MARSHALL COUNTY, OKLAHOMA
1980-1990

Other EMS Calls by Age	Year										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Under 20	28	28	29	29	30	31	32	33	34	35	36
20-29	23	24	25	26	27	29	30	31	32	33	34
30-39	9	10	10	11	11	12	12	13	14	14	15
40-49	15	16	16	17	18	19	20	21	22	23	24
50-59	34	34	35	36	36	37	38	39	40	42	43
60-64	34	34	34	35	35	35	36	36	37	37	38
65-69	24	24	24	25	25	25	25	26	26	26	26
70-79	111	114	116	119	121	124	126	128	131	133	135
Over 80	192	204	215	227	238	250	261	273	285	297	309
Total	470	488	504	525	541	562	580	600	621	640	660
Highway Accidents	48	50	51	53	55	57	58	60	63	65	67
Transfers	180	186	192	198	205	212	219	227	235	243	251
Total Calls	698	724	747	776	801	831	857	887	919	948	978

in each area; (2) identifying possible locations of first responders and vehicles; and (3) a mileage matrix which specifies miles from each possible location to each demand area. The computer model is based on the general transportation model presented in Chapter III. The model identifies the combination of locations which minimized the total cost (average response time) to get to an emergency.

The county was divided into twenty-one demand areas with the boundaries being along township lines (Figure 4). Six possible locations for vehicles or first responders were identified. Guthrie, Crescent, Marshall, Mulhall, Orlando, and the Coyle-Langston area. Map mileage from each demand point to each supply point was measured.

The computer program was designed to select two, three and four combinations of vehicles which would minimize the average miles to an emergency. Refering to Tables IV and V, the two locations which yielded the lowest average miles when two vehicles were specified were Guthrie and Crescent (Table IV). Average distance to an emergency with these locations is 3.4 miles (Table V). Similarly, if three locations were desired, Guthrie, Crescent and Coyle-Langston are the first choice with an average response mileage of 3.0 miles . Decisionmakers can see the impact of increased vehicles and the impact on response time. The next section will deal with a detailed analysis of how costs vary by the number of vehicle locations.

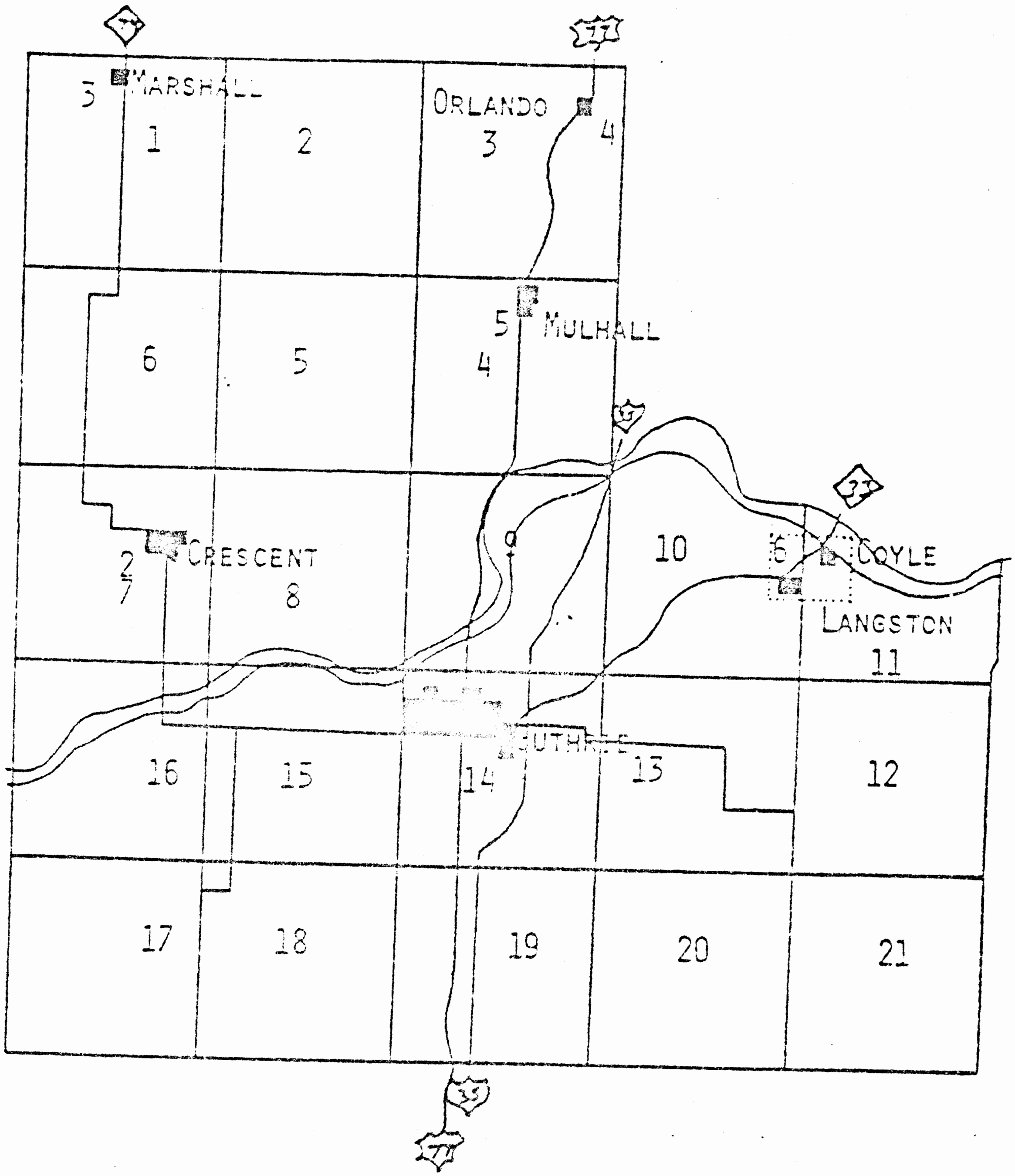

Figure 4. Demand Areas and Possible Locations for Ambulanc Services

TABLE IV

FIRST AND SECOND CHOICE LOCATIONS FOR VEHICLES, LOGAN COUNTY, OKLAHOMA

Number of Vehicle Locations	First Choice	Second Choice
2	Guthrie, Crescent	Guthrie, Marshall
3	Guthrie, Crescent Coyle-Langston	Guthrie, Crescent, Marshall
4	Guthrie, Crescent, Marshall, Coyle-Langston	Guthrie, Crescent Mulhall, Coyle-Langston

TABLE V

DISTANCE (IN MILES) TO AN EMERENCY UNDER ALTERNATIVE AMBULANCE LOCATION SCHEMES

Number of Locations	First Choice		Second Choice	
	Maximum	Average	Maximum	Average
2	20	3.4	20	5.3
3	18	3.0	20	3.1
4	15	2.6	15	2.9

Financial Analysis of Alternative EMS Systems in Logan County

Local decisionmakers contemplating multiple vehicle locations for EMS need to have an estimate of expenses of these alternatives. Data from the EMS Guidebook [21] are used in a computerized program to estimate capital and operating costs. For an explanation of the computer program, one may refer to the works of Hill et al [35].

The Logan County example is again used to illustrate the costs of multiple locations. It will be assumed decisionmakers are deciding on whether or not to have two, three, or four vehicle locations (Figure 5). The locations not having vehicles would have trained volunteers with first responder kits. The places which have vehicles would have paid volunteer EMT's. To aid decisionmakers, four alternative budgets were prepared. The first assumes two locations, the second and third assume three locations and the fourth assumes four vehicle locations. Estimated costs under these four options are summarized in Table VI. The details of each will be discussed separately int he following sections.

Estimated Costs of Alternative Systems

Option 1. Two locations with four hightop vans are considered in this budget. Their estimated cost is $25,127. The vans are to be

TABLE VI

ESTIMATED ANNUAL COSTS OF A LOGAN COUNTY EMS SYSTEM, 1982

Number of EMS Locations	Two	Three		Four
Option Number	1	2	3	4
Capital Costs				
Vehicle	$23,117	$22,782	$22,782	$22,447
Vehicle-Communications	1,070	1,337	1,337	1,605
Base Communications	569	569	569	569
Pagers	1,205	1,473	1,473	1,740
First Responders	1,335	1,001	1,001	667
Building	6,829	-	9,390	11,951
Total Capital Costs	$34,125	$27,162	$36,552	38,979
Operating Costs				
Vehicle				
Gasoline	11,730	11,560	10,929	10,873
Maintainance	9,142	10,224	10,224	11,313
Communications	500	625	625	750
Base Communications	469	469	469	469
Building				
Rent	-	10,800	-	-
Utilities	2,637	-	3,829	5,020
Medical	14,720	14,720	14,720	14,720
Labor				
Supervisor	14,950	14,950	14,950	14,950
EMT	114,967	89,419	114,967	127,742
Secretary	8,372	8,372	8,372	8,372
Volunteer	5,200	20,800	10,400	15,600
Miscellaneous & Training	2,500	3,000	3,000	3,500
Total Operating Costs	$185,187	$184,939	$192,485	$213,390
Total Costs	$219,312	$212,101	$229,037	$252,288

every 75,000 miles as was recommended by operators in the earlier study [21]. A new vehicle would be needed by the system almost every year. Total vehicle depreciation would be about $23,117 a year.

Each vehicle would need a radio. VHF vehicle communication equipment costs about $2,674 installed and has a life of 10 years. The base communication would also have a 10 year life at a cost of $7,064 installed. Dispatching would be handled by EMTs at Guthrie, unless they are on a call, then dispatching would be handled by the county sheriff. It was assumed that eleven pagers for personnel would be needed. These cost $402 each and have a 3-year life. Three first responder kits, designed to be used by trained personnel were added. These have five watt radios which have a five year life and annual depreciation of $2,335.

Buildings were assumed to be needed. They were assumed to be prefabricated buildings at each location at a cost of $27 per square foot. The annual payment on a 1250 square foot building at Guthrie and 750 square foot at Crescent on a 12.25 percent Farmers Home Administration loan would be $6,829. Total capital cost would be $34,125.

Hightop vans were assumed to get about 8 miles per gallon of gasoline. If gasoline averages $1.36 a gallon in 1982 and the vehicle travel 69,000 miles, it would cost about $11,730 in gasoline in 1982. Vehicle maintenance was also based on mileage. Tires, oil, tune-ups, insurance and miscellaneous maintainance were assumed to cost the service about $9,142 in 1982. The vehicle communications maintenance was based on the price of a service maintenance contract for a VHF radio. This was assumed to run about $500 a year, for five radios. The base communication cost was estimated in a similar fashion to be $469 per year.

Building utilities, maintenance and insurance were based on square footage. These costs were estimated to be $2,637.

Medical costs include such things as sterile bandages, equipment maintenance and linens. This cost is based on the number of ambulance calls and was calculated to be $14,720.

Labor costs include a supervisor EMT at $13,000 annually and nine EMTs each at an annual salary of $11,108 plus 15 percent for fringe benefits (such as vacations, Workman's Compensation, Social Security, retirement). Seven EMTs would be located at Guthrie and two at Crescent. Two volunteers would also be paid $50 a week to stand by at Crescent to assist the EMTs. It was assumed that a secretary would be hired at $3.50 an hour and would handle dispatching during the day from 8:00 a.m. to 5:00 p.m., Monday through Friday. Dispatching at other times would be handled by EMTs on duty. When those EMTs answer a call, the sheriff's department would be responsible for dispatching until the EMS returns.

A training and miscellaneous charge of $2,500 was added to cover such things as EMT training and office supplies. Total operating costs were estimated at $185,187. Total costs were about $219,312.

Option 2. Three locations are considered for this alternative. The same assumptions are made as in the first option except that building costs included rent. The Guthrie building was assumed to have a cost of $400 a month, bills paid while the building at Crescent and the Langston-Coyle area would be $250 a month, bills paid.

One vehicle was added. One hightop van would be at Crescent and the other location at Coyle-Langston, while two hightop vans and a transfer vehicle would be located at Guthrie. The vehicle was assumed to be a low top van, suburban, or some other type to be used for transfers only. Its cost was estimated at $10,000. This addition lowered vehicle capital costs due to fewer miles being put on the more expensive hightop vehicle. Mileage was also reduced to 68,000 miles due to the addition of an ambulance location site. Annual capital costs were $27,162.

The transfer vehicle gets 11 miles to the gallon of gasoline, lowering that cost. Other vehicle costs rose, chiefly due to insurance. The number of EMTs was decreased to seven. The seven would be placed at Guthrie and volunteers would serve the other locations. Four volunteers at each of the other locations would be paid $50 a month stand-by pay. Operating costs were $184,939 and total costs were $212,101.

Option 3. This alternative is identical to the second in that it considers three locations. A building however was assumed to be built at each location. A 1250 square foot, three bay, prefabricated building for $27 per square foot was assumed for Guthrie. A one bay station was built at the other two locations. Each contains 750 square feet. They would have an annual payment of $9,390 on a Farmers Home Administration

12.25 percent, 30 year loan. Total capital costs were $36,552. Building utilities, water, sewer, trash and insurance would also need to be paid. These were estimated to be $3,829.

Two EMT's were added, one at each of the two locations outside of Guthrie. They would be aided by two volunteers each paid $50 a week stand-by pay at each location. Operating costs were $192,485, and total costs were $229,037.

Option 4. This alternative is identical to the second, except a fourth location was added. This added one hightop van, one EMT, two volunteers and a building. Annual capital costs were $38,979, operating costs were $213,309 and total annual costs were $252,288.

Revenue Structure and Funding Alternatives

An estimate of revenue can be made by using a charge rate, plus mileage charge with variable collection rate. Referring to Table VII the total annual revenue assuming 1527 calls and an $80 base rate per calls would be $132,928.00. This would not cover costs of the first alternative in Table VI.

An EMS District could be created to finance EMS service for Logan County. Oklahoma State Amendment 522 which permits creation of an EMS District and allows for the collection of three mills on property taxes. Three mills for the county based on 1981 property tax asessment would

TABLE VII

ESTIMATED REVENUE FROM A LOGAN COUNTY EMS SYSTEM, 1982

	BASE RATE			
ESTIMATED REVENUE	$60	$70	$80	$90
Base Rate X (1527 Calls)	$91,620	$106,890	$122,160	$137,430
Mileage at $2 per mile	44,000	44,000	44,000	44,000
Total Revenue	$135,620	$150,890	$166,160	$181,430
Collection at 50%	$67,810	$75,445	$83,080	$90,715
Collection at 60%	$81,372	$90,534	$99,696	$108,858
Collection at 70%	$94,934	$105,623	$116,312	$127,001
Collection at 80%	$108,496	$120,712	$132,938	$145,144

522 EMS District:

1 Mill	$62,186
2 Mills	$124,372
3 Mills	$186,558

*1981 Evaluation

generate $186,558. This district could then contract with the city or private services to provide emergency medical services or could operate the service itself. A three mill levy plus a $60 base rate with $2.00 per mile one way charge and 50 percent collection rate would definitely support any of the alternatives.

The Probability Model As Applied to Marshall County EMS System

Decisionmakers in Marshall County were confronted with the decision of how best to supply EMS service within their financial capabilities in early 1981. Local decisionmakers contacted State Health Department and Oklahoma Cooperative Extenison Personnel for a study. A budget and location analysis similar to the one indicated above was completed [49]. In addition, information concerning the estimated number of times during a year an emergency call would come into the system while the vehicle is busy was needed.

Since funds are limited, decisionmakers of large and small systems must weight the trade-off between allocating additional funds and the benefits received from those funds. The nature of emergency calls is such that equipment and personnel are idle most of the time. More critical, however is the number of times the equipment and personnel be on a call when another emergency call occurs. This is important in deciding the number of emergency units to have.

The method described earlier in Chaper III has been developed to estimate the number of times during the year an emergency call will come in when the present unit is on call. The data necessary for this type of analysis are the number of emergency and non-emergency calls by time of day and the average length of response time per call. If a system does not have the data, estimates may be available from other similar type systems and can be used.

Madill EMS system made a total of 695 runs in the year 1980. This may be translated into 0.0795 calls per hour. If it takes an average of 68 minutes (a rate derived from an Okmulgee EMS system) to complete one service, 0.8824 services can be completed in one hour. Hence the probability of a busy period for a system at any one period is approximately nine percent. This implies that 91 percent of the time callers can get an immediate response and 9 percent of the calls will be received while the crew is out on duty. This assumes there is a 24-hour ambulance service. One of the reasons why an EMS system is expensive to run in a rural setting is that the intensity of demand, described above as the probability of a busy period is very low.

Examination of the pattern of calls show that busy periods vary by time of day. Peak periods were found to be between 8 a.m. and 4 p.m. when 57 percent of the total runs were made. Slower periods were between midnight and 8 a.m. and between 4 p.m. and midnight comprising 12 percent and 31 percent of the runs, respectively.

To analyze the level of utilization of a service, each day was divided into four-hour intervals. The number and percentage of runs made during these intervals by Madill EMS in 1980 are shown in Table VIII.

An inspection of EMS data for various EMS services in the state indicate that there are also variations in call rates depending on the type of call. Calls may be divided into two classes: (1) emergency or life-threatening situations and (2) non-emergencies -- minor accidents, hospital-to-hospital transfers or nursing home transfers. Number of both classes of EMS runs for Madill, Oklahoma, are summarized in Table IX.

Another point of interest is the expected waiting time until a call is attended by an ambulance crew. This is shown in Table X. The busiest period is noon to 4 p.m. One would need to wait a maximum of 9 minutes before a service is delivered.

The total time an EMS crew would spend to deliver service is also determined. The results are summarized in Table XI. Noon to 4 p.m. was the busiest time with 73 minutes if the case were an emergency or 80 minutes if the case were a non-emergency. Non-emergencies take longer because of typically longer distance to travel between patient location and patient destination.

The probability of a busy period is an important indicator of how early an EMS crew will arrive to provide service. The higher the probability, the longer a caller would have to wait expecially when there is only one ambulance service in the area.

The probability of a busy period is determined by the ratio and the probability of immediate response is $[1 - \rho]$. For both

TABLE VIII

MADILL EMS RUNS BY TIME OF DAY, YEAR 1980

Time of Day	Runs		Average Number of Runs Per Day
	Number	Percent	
Midnight - 4 a.m.	46	7	0.13
4 a.m. - 8 a.m.	34	5	0.09
8 a.m. - noon	180	26	0.49
Noon - 4 p.m.	218	31	0.60
4 p.m. - 8 p.m.	125	18	0.34
8 p.m. - midnight	92	13	0.25
Total	695	100	1.90

Source: [49]

TABLE IX

EMS CALL RATES AND PROBABILITY OF BUSY PERIOD BY TYPE OF CALL AND TIME OF DAY
MADILL EMS, MARSHALL COUNTY, OKLAHOMA

	Emergency Cases			Non-Emergency Cases		
Time of Day	Observed Annual Calls	Call Rate Per Period	Call Rate Service Rate	Observed Annual Calls	Call Rate Per Period	Call Rate Service Rate
Midnight - 4 a.m.	13	.0356	.0098	33	.0904	.0250
4 a.m. - 8 a.m.	10	.0274	.0075	24	.0658	.0190
8 a.m. - Noon	50	.1370	.0380	130	.3562	.1050
Noon - 4 p.m.	85	.2329	.0640	133	.3644	.1070
4 p.m. - 8 p.m.	42	.1151	.0320	83	.2274	.0670
8 p.m. - Midnight	35	.0959	.0260	57	.1562	.0460
Total	235	.6438	.1769	460	1.2603	.3707

Source: [49]

TABLE X

WAITING TIME IN A QUEUE BY TYPE OF CALL
MADILL EMS, MARSHALL COUNTY
OKLAHOMA, 1980

Time of Day	Type of Call	
	Emergency	Non-Emergency
Midnight - 4 a.m.	1	2
4 a.m. - 8 a.m.	1	1
8 a.m. - noon	3	8
Noon - 4 p.m.	5	9
4 p.m. - 8 p.m.	2	5
8 p.m. - Midnight	2	3

emergencies and non-emergencies, the probability of a delay or busy period is tabulated by time of day in Table XII. The probability of a busy time period for Madill EMS ranges from 0.77 percent between 4 a.m. and 8 a.m. to 6.6 percent from noon to 4 p.m. for an emergency case and approximately 2 percent to 11 percent in a non-emergency case.

Table XIII is constructed to show the expected number of customers that will have to wait while another service is being conducted.

The total number of calls during the year that will be received while the crew is out is 60. This is 9 percent of the total number of calls received. For emergency cases, there were 11 cases that required patients to wait in a queue. A majority of the multiple calls are expected to occur between noon and 4 p.m. A much less critical number is the number of non-emergency calls which enter the system while the ambulance is busy. This is expected to occur 49 times a year.

TABLE XI

AVERAGE TIME SPENT IN THE SYSTEM BY STATUS AND TIME OF THE DAY
MADILL EMS, 1980

Time of Day	Time Spent in the System in Minutes	
	Emergency	Non-Emergency
Midnight - 4 a.m.	67	73
4 a.m. - 8 a.m.	66	72
8 a.m. - noon	69	79
Noon - 4 p.m.	71	80
4 p.m. - 8 p.m.	68	76
8 p.m. - Midnight	69	74

TABLE XII

THE PROBABILITY OF BUSY PERIOD BY STATUS OF CALL AND TIME OF DAY
MADILL EMS, 1980

Time of Day	Call Status	
	Emergency	Non-Emergency
Midnight - 4 a.m.	.0101	0.0267
4 a.m. - 8 a.m.	.0077	0.0195
8 a.m. - Noon	.0388	0.1054
Noon - 4 p.m.	.0660	0.1078
4 p.m. - 8 p.m.	.0326	0.0673
8 p.m. - Midnight	.0272	0.0462

TABLE XIII

ANNUAL EXPECTED NUMBER OF CALLS THAT WILL WAIT IN A QUEUE
MADILL EMS

Time of Day	Emergency	Non-Emergency	Total	Percent
Midnight - 4 a.m.	0	1	1	2
4 a.m. - 8 a.m.	0	1	1	3
8 a.m. - Noon	2	18	20	11
Noon - 4 p.m.	6	19	25	11
4 p.m. - 8 p.m.	2	7	9	7
8 p.m. - Midnight	1	3	4	4
Total	11	49	60	9

CHAPTER V

EXTENSION OF THE MODELS TO MULTI-COUNTY AND STATE LEVEL MULTI-COUNTY ANALYSIS

As state and local EMS planners attempt to provide the best service possible with limited resources, it is important that the system concept is emphasized. Advanced personnel, basic personnel and first responders are all part of the system. EMS response area may clearly cross political boundaries, thus a larger than local analysis is often necessary. This chapter contains two parts useful to EMS planners. First, the study illustrates how basic life support, first responder and advanced life support systmes can be utilized for maximum protection in a multi-county region. Included in this illustration are the designated service area for each component, the average response time, and projected number of calls. A four county area in Northwestern Oklahoma is chosen to illustrate this method. Second, the complete State analysis applies only to basic life support system. This analysis involves designating service areas, estimating response time, and projecting future calls in the entire State of Oklahoma.

Multi-County Level Analysis

Determination of Service Areas

The four-county study area includes Garfield, Grant, Kay and Noble Counties in Northwest Oklahoma. To complete the analysis, the study area was divided into 112 demand areas (Figure 5). The approximate boundaries of each demand area were township lines. On the same figure the present basic life support service systems are identified. These include Wakita, Pond Creek, Medford, Enid, Newkirk, Blackwell, Ponca City, Tonkawa, Billings and Perry. Seventeen possible first responder systems are also identified. A mileage matrix was developed indicating the distance from each demand area to each supply area. Distance was used as a proxy of response time information. In addition, an estimate for the number of calls in each demand area for 1981 was obtained from run reports. Based on population projection, the number of runs expected in 1985 and 1990 were projected. The transportation model described in Chapter III is then used to delineate service areas, estimate response time and expected number of EMS calls.

Basic Life Support Service Areas and Expected Number of EMS Calls

In the Oklahoma Emergency Medical Services Improvement Act of 1981, basic life support is defined as the provision of basic ambulance

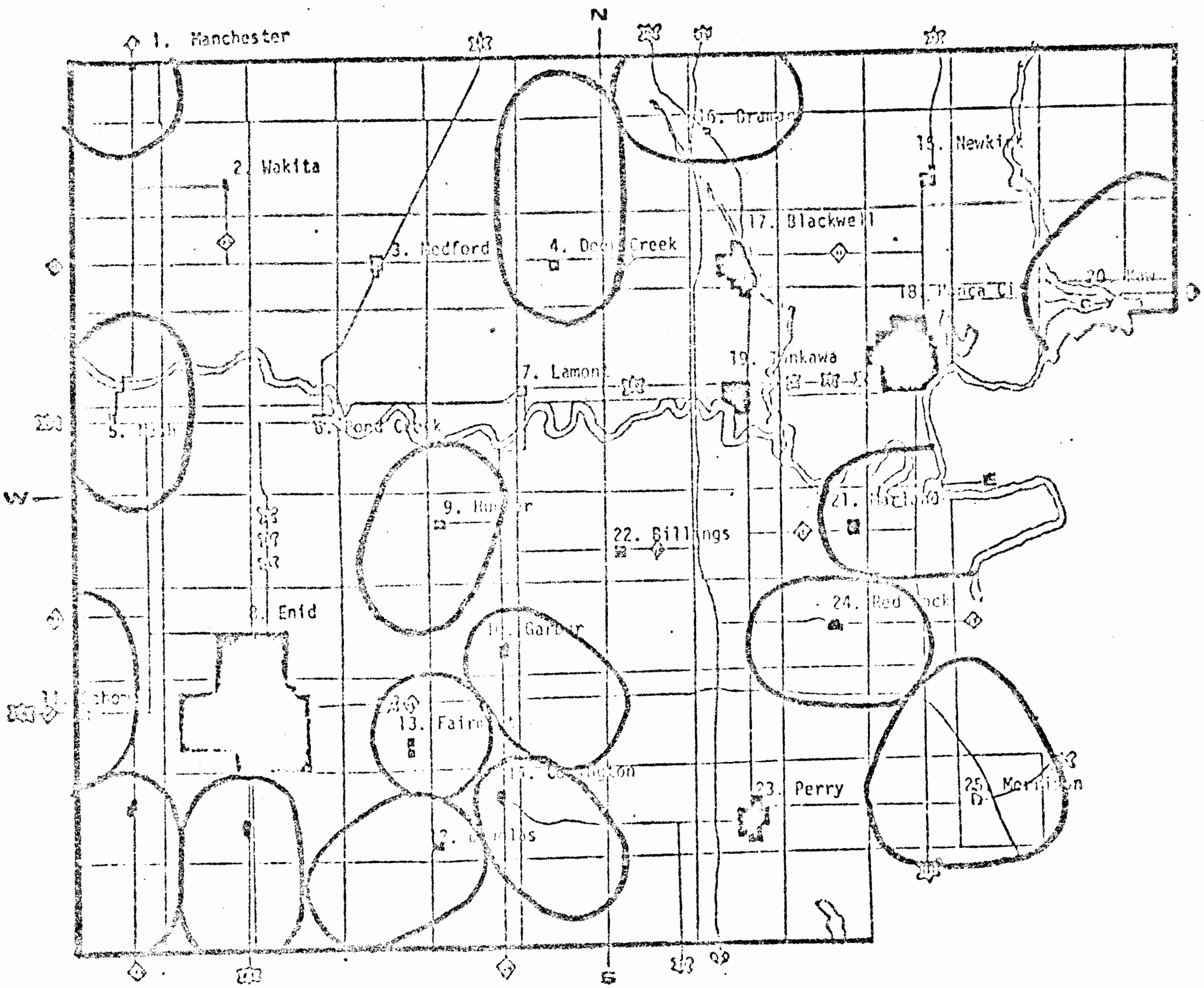

Figure 5. Designated Service Areas for First Responder System

services including appropriate vehicles, equipment, communications, dispatching and staffing by certified emergency medical technicians [21]. With this definition in mind, the cost minimizing transportation model is used to delineate which of the ten EMS locations should serve what area regardless of county border lines. These delineations are depicted in Figure 6. From the figure it can be seen that service does extend across county boundaries. For example, a service like Perry extends into Garfield County. Another example is Tonkawa which extends to three counties. Thus, if EMS systems are planned within county boundaries it may result in inefficient service delivery. The computer program is also used to estimate response time and the expected number of calls. For example, Enid service is projected to have a maximum response time of 24 minutes and an average response time of 5.19 minutes (Table XIV). In 1981, the service made 2,216 calls. These are all calls except hospital to hospital transfers and "dry runs". In 1985 and 1990, the projected number of calls are expected to be 2,357 and 2,550, respectively. For the total four-county area, 5,416 calls occurred in 1981 and the average response was 5.33 miles. The number of EMS calls is projected to increase to 5,649 in 1985 and 5,657 in 1990. Data in this table clearly indicate which services are expected to have large increases in calls in the 80s. The larger cities of Enid and Ponca City will experience the largest growth in calls. This assumes that the same utilization of EMS will exist in the 1980's. The number of calls expected by the smaller systems will remain about the same. The maximum distances that vehicles will have to travel in BLS systems clearly indicate the need for first responders.

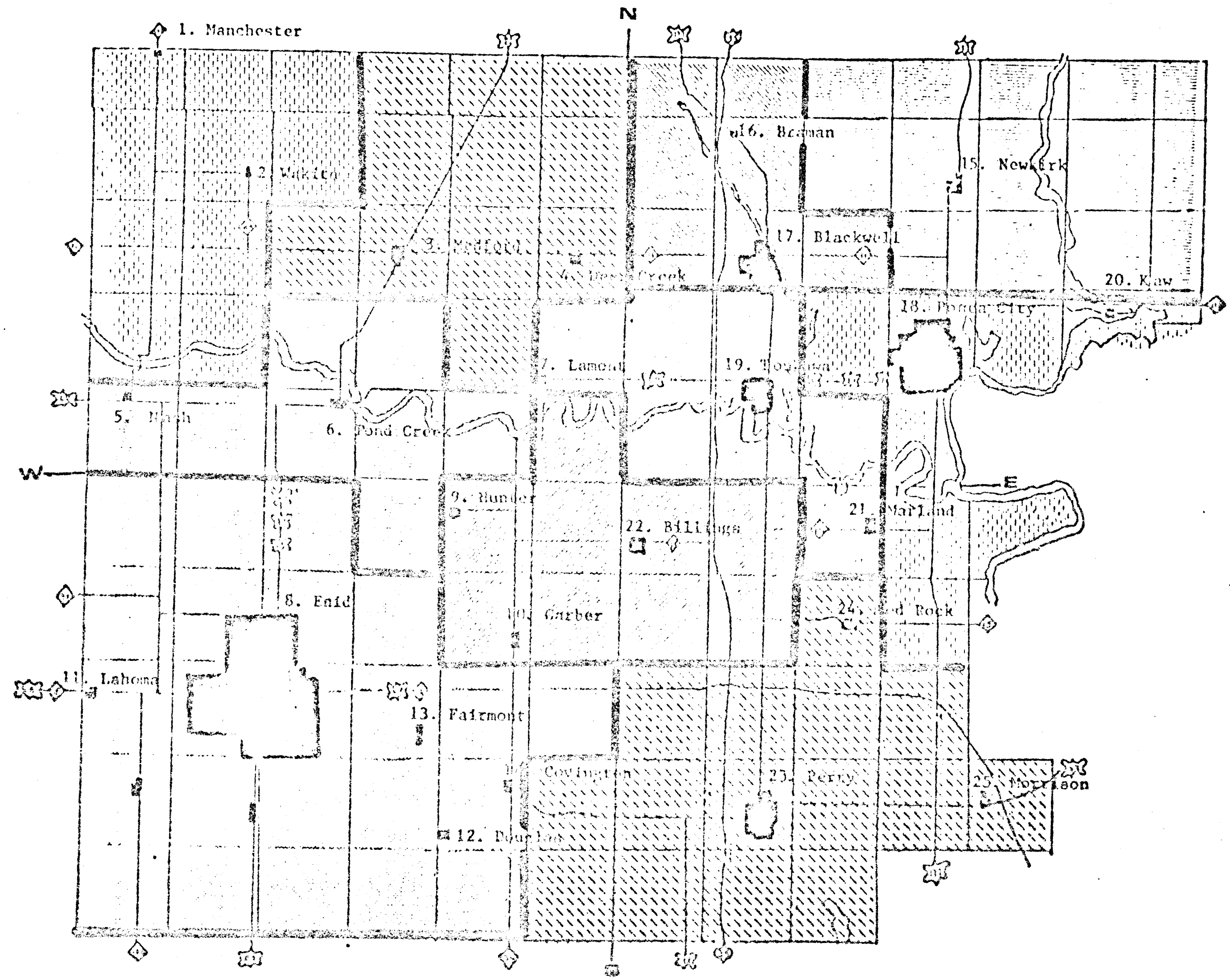

Figure 6. Designated Locations for Basic Life Support service System for a Four-county Region of Garfield, Grant, Kay and Noble

TABLE XIV

ESTIMATED RESPONSE TIME AND NUMBER OF CALLS FOR BLS SERVICE IN A FOUR COUNTY REGION OF GARFIELD, KAY, NOBLE AND GRANT COUNTIES, OKLAHOMA 1981-1990, SELECTED YEARS

Location of Service	Response Time (Min) Maximum	Average	1981 Calls	1985 Calls	1990 Calls
Wakita	14.50	7.95	33	32	32
Pond Creek	23.00	7.80	42	42	41
Medford	23.00	7.22	55	54	52
Enid	24.00	5.19	2216	2357	2550
Newkirk	23.00	6.02	225	228	235
Blackwell	14.00	4.52	560	576	590
Ponca City	17.00	4.32	1545	1582	1626
Tonkawa	16.00	5.19	265	273	281
Billings	19.00	11.32	122	129	139
Perry	28.00	8.74	353	376	411
Total	28.00	5.33	5416	5649	5957

First Responders System (FRS)

A first responder, according to the Oklahoma Emergency Medical Care Act as amended, 1981 is used to mean:

> ... an individual who has completed a standard Department of Transportaiton first responder course and has been certified by the commissioner. The first responder is allowed to perform at least the following:
>
> a. patient assessment and triage,
> b. cardiopulmunary resuscitation,
> c. basic first aid and rescue services,
> d. bandaging, splinting and control of hemorrage,
> e. spinal immobilization and stabilization of emergency patients, and
> f. other skills as designated by the Commissioner on the advice of the Technical Medical Direction Committee (21, pp. 50-51].

To complete an analysis of first responders, 17 small communities where first responders could be located were identified. The computer program was run to specify service areas and project calls. The approximate service areas are depicted in Figure 7. For example, a first responder system at Deer Creek would serve the town and surrounding area. It would have responded to 10 calls in 1981 and could expect about that many in 1985 and 1990 (Table XV). The response time and the number of calls indicate the importance of first responder teams. For example, Garber is expected to have from 60 to 70 calls each year. With this number of calls, a first responder system should be considered. For the four county area, the potential calls are projected to increase from 476 in 1981 to 500 in 1985 and 548 in 1990.

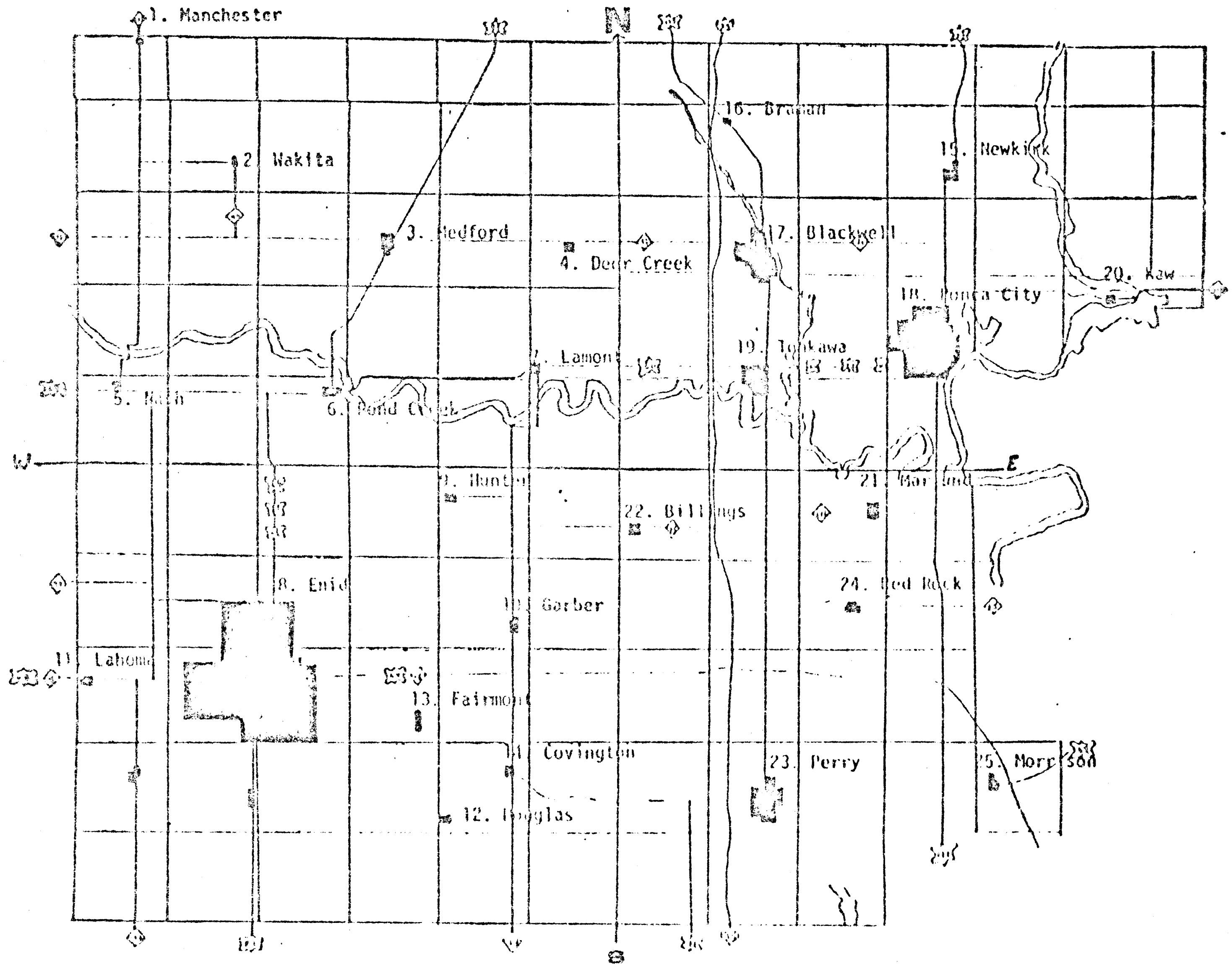

Figure 7. Possible Locations of Basic Life Support Service and First Responder System for a Four-county Region of Garfield, Grant, Kay and Noble

TABLE XV

ESTIMATED RESPONSE TIME AND NUMBER OF CALLS FOR FIRST RESPONDER SERVICE IN GARFIELD, KAY, NOBLE AND GRANT COUNTIES

Location of Team	Response Time (Min.) Maximum	Average	1981 Calls	1985 Calls	1990 Calls
Manchester	6.00	2.00	4	4	4
Deer Creek	14.00	3.10	10	10	9
Nash	8.00	2.00	10	10	10
Lamont	6.00	2.50	16	15	15
Hunter	7.00	3.05	22	24	25
Garber	8.00	2.68	62	66	72
Lahoma	6.00	2.00	28	30	32
Douglas	6.00	2.90	22	23	25
Fairmont	5.00	2.72	29	31	33
Covington	11.00	3.32	28	29	42
Braman	6.00	2.54	37	38	40
Kaw	7.00	3.14	21	21	23
Marland	6.00	2.00	15	16	18
Red Rock	7.00	3.00	20	21	24
Morrison	6.00	2.46	39	42	46
Waukomis	8.00	3.07	85	89	97
Drummond	8.00	3.07	28	31	33
Total	11.00	2.76	476	500	548

Advanced Life Support System (ALS)

The Oklahoma Emergency Medical Care Act As Amended, 1981 defined advanced life support as:

> ... the provision by an emergency medical provider of advanced emergency medical care services which:
>
> a. exceed the level of basic life support...;
> b. include the use of sophisticted transportation vehicles and equipment and telemetry communications;
> c. are staffed by advanced level certified emergency medical technicians; and
> d. are capable of providing onsite, prehospital and interhospital mobile intensive care [21, pp. 49-50].

It is difficult to estimate the threshold size a system offering ALS services. Research indicates that from three to five percent of the calls could benefit from ALS personnel. This being the case, Enid can expect from 70 to 118 ALS calls in 1985. Ponca City can expect from 47 to 79 ALS calls in 1985. The larger system will need to decide at which point they move to an ALS systems. State personnel need to be able to estimate the number of calls requiring ALS techniques, encourage the implementation of ALS systems, and be ready to offer planning assistance when requested.

State Level Analysis

Estimates of Current and Future Population of Oklahoma

Data for initial population by age and sex were obtained from the 1970 census of population [84]. For birth rates, death rates and trend the computer model uses data from the Oklahoma State Department of Health.

Net migration is the most sensitive part of the model. It is a measure of the difference between the total in-migration and out-migration of individuals and/or families into or out of a particular location. Migration is mainly influenced by several factors concerning attractive or repulsive economic and/or non-economic reasons. Even though the final decision to move may be based on weights such as a net benefit-cost ratio of moving, behavioral decision such as this is very hard to predict especially when annual data are not available. However, an average annual rate was derived from Census Bureau data from 1960-1970 and April, 1970 to July 1, 1978 as an initial rate to be used in the computer program. This rate was then adjusted to reflect the total population of 1980. Data in Table XVI show county-by-county annual migration rates used after making adjustment for 1980 populations.

Assuming that the migration rates developed above prevail for each county, and using the State Health Department's birth rate and death

TABLE XVI

ANNUAL MIGRATION RATES FOR OKLAHOMA[1]

County	Annual Migration Rate Percent
Adair	1.9500
Alfalfa	0.5650
Atoka	1.5750
Beaver	0.8000
Beckham	2.5850
Blaine	1.6000
Bryan	1.8000
Caddo	0.6600
Ccanadian	5.4500
Carter	1.6550
Cherokee	1.2500
Choctaw	1.5700
Cimarron	-1.4150
Cleveland	3.8770
Coal	1.2500
Comanche	-0.5575
Cotton	1.0450
Craig	0.4600
Creek	2.2610
Custer	0.8710
Delaware	0.3270
Dewwy	0.8000
Ellis	1.3450
Garfield	1.0000
Garvin	1.3420
Grady	2.9750
Grant	-0.1900
Greer	-0.4700
Harmon	-0.6800
Harper	-0.8700
Haskett	1.5050
Hughes	1.3790
Jackson	-0.7340
Jefferson	2.2000
Johnston	3.1020
Kay	0.2000
Kingfisher	0.9450
Kiowa	0.7200
Latimer	1.2350
LeFlore	2.3580
Lincoln	3.1200
Logan	2.9580
Love	3.0800
McClain	3.6000

TABLE XVI (Continued)

County	Annual Migration Rate Percent
McCurtain	2.2200
McIntosh	2.4900
Major	1.8070
Marshal	3.7700
Mayes	3.2800
Murray	1.6800
Muskogee	1.0360
Noble	1.7400
Nowata	1.9170
Okfuskee	0.6660
Okmulgee	1.1250
Osage	2.6570
Ottawa	0.6750
Pawnee	2.9530
Payne	1.1500
Pittsburg	1.0750
Pontotoc	1.6000
Pottawatomie	2.1600
Pshmataha	2.6700
Roger Mills	0.9760
Rogers	4.4730
Seminole	1.2000
Sequoyah	2.4010
Stephens	1.8610
Texas	0.3000
Tillman	-0.1500
Wagoner	6.2185
Washington	1.0380
Washita	1.5490
Woods	-0.9000
Woodward	3.0460

[1] Oklahoma and Tulsa Counties are not included here.

rate statistics, the State's population (county-by-county) was projected to the years 1980 - 1990. The projected population for the years 1981, 1985, 1990 is presented in Table XVII.

Estimates of Current and Future EMS Calls in the State of Oklahoma

In Table XVIII and XIX are presented EMS utilization rates per 1000 population for highway accident calls and other medical (plus nursing home transfer service) calls for the years 1981, 1985 and 1990. Utilization rates for other medical calls by age group and by county are available from the Oklahoma State University's Agricultural Economics Department, Extension Division.

The projected number of EMS calls for the years 1981, 1985 and 1990 are presented in Table XX. The number of calls obtained for each county may appear small due to the fact that the number of transfer calls from hospital-to-hospital and the number of "dry runs" have not been included.

In 1981, Comanche, Rogers, Cleveland, Okmulgee and Garfield stood among the top five counties with the highest number of highway accident calls. The range was from 294 in Garafield to 472 in Comanche. In other medical calls, Cleveland, Muskogee, Comanche, Kay and Okmulgee counties were the topfive. The number of calls ranged form 2278 in Okmulgee to 3452 in Cleveland. Overall, Cleveland, Comanche, Muskogee,

TABLE XVII

PROJECTED POPULATION FOR OKLAHOMA 1981-1990, SELECTED YEARS[1]

County	1981	1985	1990
Adair	18,836	20,536	22,944
Alfalfa	7,013	7,001	7,003
Atoka	12,897	13,751	14,394
Beaver	6,868	7,102	7,409
Bechkam	19,641	21,470	24,153
Blaine	13,608	14,454	15,659
Bryan	30,824	33,130	36,358
Caddo	31,009	32,005	33,382
Canadian	59,529	74,643	99,076
Carter	44,233	48,278	51,535
Cherokee	31,279	34,868	39,910
Choctaw	17,322	18,363	19,869
Cimmaron	3,607	3,435	3,230
Cleveland	138,987	167,207	209,565
Coal	6,044	6,307	6,693
Comanche	112,098	112,976	113,498
Cotton	7,367	7,617	7,977
Craig	14,887	15,019	15,243
Creek	59,428	65,697	74,560
Custer	26,257	27,648	29,442
Delaware	24,488	27,680	32,415
Dewey	5,865	5,977	6,151
Ellis	5,637	5,977	6,151
Garfield	63,399	66,688	71,076
Garvin	28,099	29,516	31,494
Grady	40,227	45,363	52,870
Grant	6,466	6,291	6,115
Greer	6,805	6,482	6,147
Harmon	4,469	4,290	4,104
Harper	4,625	4,467	4,287
Haskell	11,090	11,760	12,697
Hughes	14,405	14,977	15,826
Jackson	30,275	30,078	29,790
Jefferson	8,387	8,979	9,846
Johnston	10,629	11,937	13,870
Kay	49,834	50,395	51,188
Kingfisher	14,218	14,847	15,718
Kiowa	12,719	12,892	13,197
Latimer	9,916	10,486	11,216
LeFlore	41,161	45,300	51,230
Lincoln	26,584	29,967	34,954
Logan	27,397	31,074	36,451
Love	7,646	8,593	9,986
McClain	20941	24,272	29,252
McCurtain	36,732	40,468	45,805
McIntosh	15,801	17,351	19,596

TABLE XVII (Continued)

County	1981	1985	1990
Major	8,904	9,519	10,388
Marshall	10,844	12,366	14,660
Mayes	33,067	37,694	44,510
Murray	12,178	12,883	13,901
Muskogee	66,908	70,177	74,655
Noble	11,802	12,596	13,722
Nowata	11,575	12,396	13,568
Okfuskee	11,098	11,361	11,762
Okmulgee	39,517	41,389	43,995
Osage	32,534	44,176	43,995
Ottawa	32,534	33,627	35,057
Pawnee	14,917	16,604	19,078
Payne	65,359	68,207	74,454
Pittsburg	41,873	43,755	46,313
Pontotoc	33,198	35,460	38,580
Pottawatomie	54,768	59,974	67,313
Pushmataha	12,048	13,315	15,178
Roger Mills	4,739	4,871	5,063
Rogers	47,674	57,613	72,984
Seminole	27,865	29,100	30,854
Sequoyah	31,303	34,947	40,150
Stephens	43,823	47,217	51,900
Texas	17,922	18,508	19,228
Tillman	12,370	12,281	12,225
Wagoner	44,439	57,379	79,029
Washington	48,636	51,186	54,519
Washita	13,911	14,701	15,810
Woods	10,836	10,484	10,075
Woodward	21,775	25,686	28,916

[1] Oklahoma and Tulsa Counties are not included.

TABLE XVIII

UTILIZATION RATES FOR HIGHWAY ACCIDENT CALLS BY COUNTY PER 1000 POPULATION[1,2]

County	Utilization Rate
Adair	1.78
Alfalfa	(3.27)
Atoka	(2.84)
Beaver	5.36
Beckham	6.48
Blair	4.72
Bryan	(5.81)
Caddo	5.57
Canadian	2.96
Carater	3.79
Cherokee	(5.31)
Choctaw	2.56
Cimmaron	5.11
Coal	1.35
Comanche	4.21
Cotton	5.75
Craig	(3.43)
Creek	4.93
Custer	2.93
Delaware	(3.41)
Dewey	7.79
Ellis	(4.70)
Garfield	(4.63)
Garvin	3.43
Grady	3.20
Grant	(2.87)
Greeg	3.74
Harmon	(4.43)
Harper	4.88
Haskell	2.77
Hughes	(3.08)
Jackson	4.69
Jefferson	3.24
Johnston	(3.49)
Kay	(5.10)
Kingfisher	3.82
Ikowa	4.45
Latimer	3.68
LeFlore	3.35
Lincoln	4.21
Logan	4.42
Love	5.32
McClain	(6.69)
McCurtain	4.29
McIntosh	(5.12)
Major	4.79

TABLE XVIII (Continued)

County	Utilization Rate
Marshall	(4.57)
Mayes	4.29
Murray	6.18
Muskogee	(1.88)
Noble	2.89
Nowata	2.26
Okfuskee	3.87
Okmulgee	(7.47)
Osage	(7.47)
Ottawa	(5.72)
Pawnee	6.17
Payne	(3.79)
Pittsburg	(4.15)
Pontotoc	2.93
Pottawattomie	5.01
Pushmataha	(6.45)
Roger Mills	3.93
Rogers	8.94
Seminole	3.81
Sequoyah	3.48
Stephens	(3.71)
Texas	4.56
Tillman	(5.31)
Wagoner	3.92
Washington	2.93
Washita	2.68
Woods	(6.08)
Woodward	2.36

[1] Numbers in parenthesis are determined from primary data (i.e. based on operator's records). All other values are based on a four year average of fatalities and injuries calculated from Highway Patrol Records.

[2] Oklahoma and Tulsa Counties not included here.

TABLE XIX

EMS UTILIZATION RATES PER 1000 POPULATION FOR OTHER MEDICAL CALLS AND NURSING HOME TRANSFERS, 1981-1990, SELECTED YEARS

County	1981	1985	1990
Adair	18.836	20.536	22.944
Alfalfa	7.013	20.536	7.033
Atoka	12.897	13.751	14.941
Beaver	6.68	7.102	7.409
Beckham	19.631	21.470	24.153
Blaine	13.608	14.454	15.659
Bryan	30.824	33.130	36.358
Caddo	31.009	32.005	33.382
Canadian	59.529	74.643	99.076
Carter	44.233	47.278	51.535
Cherokee	31.279	34.868	39.910
Choctaw	36.450	36.450	36.450
Cimarron	3.607	3.435	3.230
Cleveland	138.987	167.207	209.565
Coal	6.044	6.307	6.693
Comanch	112.098	12.976	113.498
Cotton	36.450	36.450	36.450
Craig	14.887	15.049	15.243
Creek	59.428	65.697	74.560
Custer	26.259	27.648	29.44
Delaware	24.488	27.680	32.415
Dewey	5.865	5.977	6.151
Ellis	5.637	5.869	6.151
Garfield	63.399	66.688	71.076
Garvin	28.099	29.516	31.494
Grady	40.277	45.363	52.870
Grant	6.466	6.291	6.115
Greer	6.805	6.482	6.147
Harmon	4.469	4.290	4.104
Harper	4.625	4.467	4.287
Haskel	11.090	11.760	12.697
Hughes	48.790	48.790	48.790
Jackson	30.275	30.078	29.790
Jefferson	8.387	3.979	9.845
Johnston	10.629	11.937	13.870
Kay	49.834	50.395	51.188
Kingfisher	14.218	14.847	15.718
Kiowa	12.719	12.892	13.197
Latimer	9.916	10.486	11.216
LeFlore	41.161	45.300	51.230
Lincoln	26.584	29.967	34.954
Logan	36.450	36.450	36.450
Love	36.450	36.450	36.450

TABLE XIX (Continued)

County	1981	1985	1990
McClain	20.941	24.272	29.252
McCrutain	36.732	40.468	45.805
McIntosh	15.801	17.351	19.596
Major	36.450	36.450	36.450
Marshall	10.844	12.366	14.660
Mayes	36.450	36.450	36.450
Murray	36.450	36.450	36.450
Muskogee	66.908	70.177	74.655
Noble	66.908	70.177	74.655
Nowata	36.450	36.450	36.450
Okfuskee	36.450	36.450	36.450
Okmulgee	39.517	41.389	43.995
Osage	36.450	36.450	36.450
Ottawa	32.534	33.627	35.057
Pawnee	36.450	36.450	36.450
Payne	53.359	68.207	74.457
Pittsburg	41.873	43.755	46.313
Pontotoc	36.450	36.450	36.450
Pottawatomie	36.450	36.450	36.450
Pushmataha	12.-48	13.315	15.178
Roger Mills	36.450	36.450	36.450
Rogers	28.330	28.330	28.330
Seminole	27.865	30.100	30.854
Sequoyah	36.450	36.450	36.450
Stephens	43.823	47.217	51.900
Texas	36.450	36.450	36.450
Tillman	12.370	12.370	12.370
Wagoner	44.439	57.379	79.029
Washington	36.450	36.450	36.450
Washita	36.450	36.450	36.450
Woods	10.836	10.484	10.075
Woodward	36.450	36.450	36.450

[1] Utilization rate is the average for all age-sex cohorts

Okmulgee, and Kay were the top five with total number of calls ranging from 2571 in Kay to 3837 in Cleveland. The lowest number of calls were 160 in Ellis County.

Designating Service Areas for Basic Life Support System in the State of Oklahoma

As EMS health department personnel work with local decisionmakers, it will be useful for them to have as resource material suggested areas for EMS systems in Oklahoma. If a county or community is considering changes, this document can be used to illustrate what their system area will probably look like. It will make local decisionmakers more aware of the fact that service areas need not follow county lines.

For this analysis, the state was divided into 2046 demand areas. The population of each demand area was determined using a housing count and population density figures presented in Appendix A. In addition, the location of EMS systems were identified on the map. The source of EMS systems was obtained from the EMS registry [64]. There were 164 cities which had EMS services according to that document. Despite the fact that some EMS Systems are listed as a county system, the individual service locations are used in the analysis. The large metro systems (Oklahoma City and Tulsa) were excluded from the analysis. A mileage matrix was completed which measured the distance from each service to each demand area. The assignment of demand areas to each service was done using the transportation model. The model as presented in Chapter

III minimizes costs subject to linear constraints. After the assignment is made, the expected number of calls, the maximum duration and the average duration were summarized and tabulated in Table XXI.

Results and Interpretation

The expected number of calls in 1981, 1985 and 1990 for each service are summarized in Table XXII. In addition, the average and maximum response time for each service is summarized for 1981. The number of calls include all calls except hospital to hospital transfers. Initial data on highway accident calls are obtained from Highway Patrol records. Based on past trends and expected area population growth, projections are made to the years 1985, 1990. Other medical calls were projected on the basis of population. The methodology for projecting these calls can be found in Chapter III.

An interpretation of the results will assist in understanding the possible use of this analysis. Consider the service area of the Seiling EMS service (Dewey County). It extends into three counties. The service responded to 138 calls in 1981. The average response time in miles was 6.4 and the maximum 23. In 1985, the service can expect 146 calls and 157 calls in 1990. An analysis of this sort can provide insite into future needs, especially while working with residents and leaders in other counties to derive an equitable financial scheme.

TABLE XX

PROJECTED EMS CALLS DUE TO HIGHWAY ACCIDENTS, OTHER MEDICAL SERVICES AND NURSING HOME TRANSFERS

County	1981			1985			1990		
	Highway Accidents	Other Medical	Total	Highway Accidents	Other Medical	Total	Highway Accidents	Other Medical	Total
Adair	34	663	697	37	725	762	41	814	855
Alfalfa	23	382	405	23	380	403	23	377	400
Atoka	37	218	255	39	233	272	42	253	295
Beaver	37	246	283	38	266	304	40	288	328
Beckham	127	881	1008	139	955	1094	157	1061	1218
Blaine	64	552	616	68	585	653	74	629	703
Bryan	179	1867	2046	193	2006	2199	211	2202	2413
Caddo	173	1139	1312	178	1184	1362	186	1237	1423
Canadian	176	1855	2031	221	2373	2594	293	3244	3537
Carter	168	1686	1854	179	1820	1999	195	1997	2192
Cherokee	166	1406	1572	185	1578	1763	212	1825	2037
Choctaw	44	719	763	47	755	802	51	803	854
Cimarron	18	120	138	18	118	136	16	115	131
Cleveland	385	3452	3837	463	4318	4781	581	5745	6326
Coal	8	166	174	9	171	180	9	178	187
Comanche	472	2596	3068	476	2771	3247	478	3024	3502
Cotton	42	310	352	44	321	365	46	336	382
Craig	51	645	696	52	651	703	52	661	713
Creek	293	2028	2321	324	2266	2590	368	2613	2981
Custer	77	859	936	81	910	991	86	983	1069
Delaware	84	652	736	94	737	831	111	864	975
Dewey	46	256	302	47	264	311	48	271	319
Ellis	27	133	160	28	139	167	29	146	175
Garfield	294	2047	2341	309	2182	2491	329	2367	2696
Garvin	96	1126	1222	101	1195	1296	108	1279	1387

TABLE XX (continued)

County	1981 Highway Accidents	1981 Other Medical	1981 Total	1985 Highway Accidents	1985 Other Medical	1985 Total	1990 Highway Accidents	1990 Other Medical	1990 Total
Grady	129	1529	1658	145	1728	1873	169	2015	2184
Grant	19	129	148	18	126	144	18	122	140
Greer	26	335	361	24	318	342	23	293	316
Harmon	20	250	270	19	240	259	18	230	248
Harper	23	173	196	22	170	192	21	167	188
Haskell	31	431	462	33	460	493	35	498	533
Hughes	44	703	747	46	731	777	49	772	821
Jackson	142	865	1007	141	884	1025	140	902	1042
Jefferson	27	396	423	29	420	449	32	454	486
Johnston	37	362	399	42	404	446	48	460	508
Kay	254	2317	2571	257	2373	2630	261	2439	2700
Kingfisher	54	514	568	57	538	595	60	574	634
Kiowa	57	579	636	57	583	640	59	586	645
Latimer	37	356	393	39	381	420	41	411	452
LeFlore	138	1551	1689	152	1713	1865	172	1938	2110
Lincoln	112	1064	1176	126	1202	1328	147	1398	1545
Logan	121	1034	1155	137	1156	1293	161	1325	1486
Love	41	311	352	46	352	398	53	406	459
McClain	140	839	979	162	973	1135	196	1172	1368
McCurtain	158	1300	1458	174	1436	1610	197	1631	1828
McIntosh	81	671	752	89	738	827	100	832	932
Major	43	356	399	46	373	419	50	421	471
Marshall	50	486	536	57	560	617	67	660	727
Mayes	142	1236	1378	161	1426	1587	191	1702	1893
Murray	75	527	602	80	551	631	86	587	673
Muskogee	126	3274	3400	132	3434	3566	140	3653	3793
Noble	34	341	375	36	363	399	40	396	436
Nowata	26	484	510	28	519	547	31	566	597

TABLE XX (continued)

County	1981 Highway Accidents	1981 Other Medical	1981 Total	1985 Highway Accidents	1985 Other Medical	1985 Total	1990 Highway Accidents	1990 Other Medical	1990 Total
Okfuskee	43	448	491	44	458	502	46	465	511
Okmulgee	295	2278	2573	309	2389	2698	329	2544	2873
Osage	206	1463	1669	229	1676	1905	262	1957	2219
Ottawa	186	1474	1660	192	1559	1751	201	1662	1863
Pawnee	92	634	726	102	755	857	117	806	923
Payne	240	1875	2115	259	2022	2281	282	2258	2540
Pittsburg	174	1573	1747	182	1666	1848	192	1790	1982
Pontotoc	97	1279	1376	104	1373	1477	113	1492	1605
Pottawatomie	274	2037	2311	300	2234	2534	337	2516	2853
Pushmataha	78	404	482	86	446	532	98	501	599
Roger Mills	19	202	221	19	211	230	20	220	240
Rogers	426	1288	1714	515	1350	1865	652	1632	2284
Seminole	106	1141	1247	111	1193	1304	118	1259	1377
Sequoyah	97	1011	1108	101	1145	1246	107	1339	1446
Stephens	163	943	1106	175	1039	1214	193	1167	1360
Texas	82	534	616	84	570	654	88	619	707
Tillman	66	439	505	65	434	499	65	427	492
Wagoner	174	1434	1608	225	1889	2114	310	2660	2970
Washington	142	1624	1766	150	1776	1926	160	1976	2136
Washita	37	562	599	39	599	638	42	648	690
Woods	66	385	451	64	371	435	61	357	418
Woodward	51	773	824	58	895	953	68	1069	1137
Totals	8423	72217	80640	9161	79105	88266	10252	89286	99538

TABLE XXI

PROJECTED NUMBER OF CALLS, WITH AVERAGE AND MAXIMUM RESPONSE TIME FOR OKLAHOMA COMMUNITIES PROVIDING BLS SERVICE, 1981-1990, SELECTED YEARS[1]

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Adair	Stilwell	664	23.00	7.48	724	812
Alfalfa	Carmen	101	15.00	5.39	100	99
	Cherokee	217	22.00	6.71	217	215
	Helena	114	13.00	5.48	114	114
Atoka	Atoka	245	20.00	8.23	261	282
Beaver	Beaver	217	34.00	10.60	234	251
Beckham	Carter	56	24.00	6.92	60	65
	Elk City	659	30.00	2.81	713	793
	Erick	131	21.00	4.38	141	157
	Sayre	238	21.00	4.10	257	286
Blaine	Canton	137	16.00	4.24	145	154
	Geary	150	18.00	4.76	171	204
	Okeene	127	17.00	5.34	134	144
	Watonga	286	14.00	2.86	304	327
Bryan	Colbert	315	20.00	6.14	339	370
	Durant	1,706	28.00	5.45	1,834	2,011
Caddo	Anadarko	431	16.00	2.26	446	466
	Binger	174	21.00	6.86	178	186
	Carnegie	266	28.00	6.86	275	288
	Cyril	182	15.00	4.28	189	198
	Hinton	126	15.00	2.62	134	146
Canadian	El Reno	640	13.00	1.66	818	1,114
	Yukon	1,249	11.00	2.30	1,596	2,177

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Carter	Ardmore	1,233	14.00	3.90	1,329	1,458
	Healdton	491	22.00	10.01	519	568
	Lone Grove	199	15.00	2.74	215	236
Cherokee	Talequah	1,522	22.00	4.28	1,709	1,971
Choctaw	Hugo	479	38.00	10.07	501	535
Cimarron	Boise City	134	38.00	8.96	132	127
Cleveland	Norman	3,584	13.00	1.88	4,468	5,912
	Noble	184	8.00	2.10	229	403
Coal	Coalgate	173	20.00	5.30	179	188
Comanche	Fletcer	157	14.00	5.10	166	179
	Lawton	2,847	23.00	1.86	3,015	3,253
Cotton	Temple	137	22.00	10.38	143	150
	Walters	220	18.00	4.14	230	242
Craig	Ketchm	382	12.00	7.98	464	534
	Vinita	451	18.00	2.50	456	461
	Welch	151	22.00	6.97	152	154
Creek	Bristow	467	17.00	3.61	520	601
	Drumright	338	9.00	4.75	378	434
	Mannford	219	15.00	6.73	249	279
	Sapulpa	1,351	9.00	2.42	1,509	1,736
Custer	Clinton	426	26.00	3.02	449	487
	Thomas	115	16.00	4.40	123	130
	Weatherford	547	18.00	4.29	576	619
Delaware	Grove	252	14.00	5.61	285	335
	Jay	415	31.00	14.01	471	548

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Dewey	Leedey	77	26.00	10.28	80	83
	Seiling	138	23.00	6.41	146	157
	Taloga	53	32.50	4.84	55	57
	Vivi	112	24.00	5.76	123	134
Ellis	Arnett	26	24.00	9.06	27	29
	Shattuck	117	20.00	5.98	122	128
Garfield	Enid	2,296	28.00	10.76	2,443	2,642
Garvin	Elmore City	175	13.00	7.67	186	200
	Linday	341	19.00	4.47	368	409
	Maysville	267	20.00	7.09	294	332
	Pauls Valley	365	5.00	1.49	387	414
Garvin	Stratford	361	18.00	9.37	389	430
Garvin	Wynnewood	245	19.00	4.68	259	277
Grady	Chickasha	1,141	17.00	3.35	1,290	1,503
	Tuttle	292	26.00	2.92	331	388
Grant	Medford	64	23.00	8.03	62	60
	Pond Creek	49	19.00	7.24	49	48
	Wakita	38	19.00	7.80	37	36
Greer	Granite	107	13.00	2.88	103	93
	Mangum	237	21.00	3.24	224	207
Harmon	Hollis	261	19.00	4.11	248	237
Harper	Buffalo	53	21.00	9.44	53	50
	Laverne	180	28.00	6.63	178	179
Haskell	Stigler	377	18.00	7.23	405	437
Hughes	Holdenville	383	17.50	1.88	398	420
	Wetumka	310	16.00	6.54	320	335

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Jackson	Altus	933	20.00	3.20	948	966
	Eldorado	78	14.00	6.79	79	80
Jefferson	Ryan	950	19.00	4.24	95	102
	Waurika	190	28.00	8.97	190	206
Johnson	Tishomingo	393	26.00	9.90	441	500
Kay	Blackwell	577	17.00	2.33	593	608
	New Kirk	208	23.00	4.09	211	218
	Ponca City	1,662	25.00	2.13	1,715	1,777
	Tonkawa	235	9.00	1.62	241	248
Kingfisher	Cashion	152	12.00	7.95	178	222
	Hennesey	169	15.00	3.36	178	190
	Kingfisher	323	18.00	3.70	337	361
Kiowa	Hobart	279	24.00	2.41	281	284
	Lone Wolf	55	10.00	3.43	56	56
	Mountain Park	210	26.00	5.55	213	217
	Montain View	117	15.00	4.32	120	122
Latimer	Wilburton	302	24.00	6.65	321	347
LeFlore	Heavener	296	46.00	11.36	326	370
	Poteau	539	32.00	5.84	595	673
	Spiro	792	31.00	9.68	874	989
	Talihina	237	38.00	12.11	261	292
Lincoln	Chandler	343	12.00	3.78	387	450
	Davenport	99	8.00	2.45	111	130
	Meeker	199	12.00	4.17	225	264
	Prague	299	13.00	4.03	334	378

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	MAXIMUM DURATION	AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	1990
	Stroud	237	9.00	2.06	268	312
	Wellston	101	22.00	5.35	115	134
Logan	Crescent	185	19.00	4.97	206	232
	Guthrie	852	18.00	3.26	955	1096
	Langston	163	17.00	7.86	181	205
Love	Marietta	578	24.00	5.73	654	753
Major	Fairview	327	23.00	7.59	344	386
Marshal	Madill	539	17.00	6.90	619	726
Mayes	Locust Grove	350	14.00	5.40	401	478
	Pryor	782	12.00	3.50	900	1073
McClain	Blanchard	482	20.00	7.39	558	671
	Purcell	399	11.00	2.49	469	575
McCurtain	Broken Bow	644	49.00	12.30	701	786
	Idabel	809	34.00	9.03	892	1014
McIntosh	Chocotah	464	15.00	6.48	506	565
	Eugaula	313	15.00	6.27	344	387
Murray	Sulfur	582	26.00	5.03	607	648
Muskogee	Ft. Gibson	362	13.00	5.50	396	448
	Haskell	272	13.00	5.00	297	339
	Muskogee	2568	12.00	1.58	2722	2947
	Warner	297	13.00	5.80	301	321
Noble	Billings	65	17.00	7.71	68	75
	Perry	292	28.00	4.66	314	338
Nowata	Nowata	509	35.00	7.53	545	597
Okfuskee	Okemah	344	11.00	3.74	352	359

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Okmulgee	Beggs	223	21.00	5.30	234	299
	Henryetta	839	22.00	3.70	883	944
	Okmulgee	1567	18.00	2.40	1644	1749
Osage	Barnsdall	515	15.00	11.49	586	685
	Fairfax	170	15.00	2.35	197	228
	Hominy	536	26.00	9.,92	610	710
	Shidler	121	30.00	5.35	139	161
Ottawa	Afton	94	4.00	3.68	98	105
	Commerce	67	8.50	4.37	71	75
	Fairland	252	16.50	9.03	266	284
	Miami	994	13.50	1.12	1048	1115
	Picher	231	8.50	1.25	244	259
	Quapaw	22	8.00	4.73	23	24
Pawnee	Cleveland	566	14.00	5.66	430	463
	Pawnee	271	18.00	3.83	319	345
Payne	Cushing	457	18.00	4.93	493	653
	Glencoe	75	24.00	7.45	81	90
	Stillwater	1,339	17.00	1.36	1,444	1,613
Pittsburg	Hartshorne	256	25.00	4.99	273	292
	McAlester	1,380	30.00	5.61	1,460	1,565
	Quinton	192	15.00	6.78	205	219
Pontotoc	Ada	1,381	23.00	5.22	1,476	1,601
	Allen	214	26.00	11.25	266	239
Pottawatomie	Shawnee	1,961	15.50	5.74	2,149	2,422
Pushmataha	Antlers	347	36.00	7.12	383	430
	Clayton	117	25.00	9.70	132	144

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Roger Mills	Cheyenne	193	19.00	2.66	200	208
	Reydon	16	27.00	8.06	17	18
Rogers	Catoosa	236	17.00	5.79	257	315
	Chelsea	231	14.00	5.94	254	311
	Claremore	1,271	24.00	6.93	1,382	1,694
Seminole	Maud	264	24.00	8.16	287	322
	Seminole	632	17.50	3.34	659	697
	Wewoka	453	24.50	4.97	476	502
Sequoyah	Sallisaw	1,015	23.00	9.90	1,140	1,324
Stephens	Comanche	120	19.00	3.86	131	148
	Duncan	756	17.00	2.22	830	930
	Marlow	335	20.00	6.22	371	423
Texas	Goodwell	52	26.50	2.41	55	59
	Guymon	365	38.00	7.24	390	420
	Hooker	150	18.00	5.86	160	172
	Texhoma	51	37.00	9.69	54	59
Tillman	Frederick	422	22.00	5.59	417	413
	Grandfield	103	32.00	5.51	103	102
Wagoner	Coweta	816	12.00	4.12	1,071	1,506
	Wagoner	628	6.00	1.75	826	1,160
Washington	Bartlesville	1,857	31.00	3.23	2,038	2,267
Washita	Burns Flat	194	13.00	4.87	205	222
	Cordell	195	14.00	2.87	209	255
	Sentinel	125	14.00	5.79	131	142

TABLE XXI (Continued)

COUNTY	BLS AMBULANCE SERVICE LOCATION	1981 ESTIMATED CALLS	1981 MAXIMUM DURATION	1981 AVERAGE DURATION	NUMBER OF ESTIMATED CALLS 1985	NUMBER OF ESTIMATED CALLS 1990
Woods	Alva	313	25.00	1.98	303	291
	Freedom	36	26.00	8.11	35	34
	Waynoka	119	36.00	9.03	117	118
Woodward	Woodard	755	22.00	2.94	873	1,040
Total		80,368			87,996	99,278

[1]Oklahoma and Tulsa Counties are not included.

CHAPTER VI

SUMMARY, CONCLUSION, IMPLICTIONS AND LIMITATIONS

Objectives and Procedure

The overall objective of this research is to develop planning tools for the analysis of current and future needs for EMS systems in the State of Oklahoma. It is primarily designed to provide information beneficial to either state planners, local decisionmakers or EMS operators in their attempt to plan EMS systems that can fulfill certain performance criteria such as efficiency, effectiveness and equitability. Two levels of problems are considered. The first part of the problem is one that arises as local EMS systems are planned within the context of county boundaries. The second part of the problem is one that emerges when these local plans fail to accomodate coverage of services irrespective of county lines. It is believed that some level of inefficiency can be created if county border lines are strickly adhered to in planning EMS districts.

In this research specific effort is made to develop interrelated models to determine (a) the number of current and future EMS calls; (b) a strategy of optimum location(s) for EMS systems in the rural areas of Oklahoma; (c) cost-revenue analysis for alternative systems; and (d) the probability that an EMS system will be adequate to meet most emergency calls. The types of services considered are (1) basic life support; (2) advanced life support; and (3) first responder systems.

To achieve the objectives, the procedure followed consists of a series of four interrelated steps utilizing the models mentioned above. The first step involves the use of a population projection model to estimate current and future calls in the rural and semi-rural areas of the State of Oklahoma. Emergency medical service calls are defined to be the sum of highway accident calls and other medical service calls including nursing home transfers. Highway accidents are assumed to be directly proportional to the size of a given population. Other medical calls are considered to be a function of the size of population by age group.

Utilization rates per 1000 population for both highway accidents and other medical calls including nursing home transfers are determined in order to estimate current and future calls for EMS. Two alternative sources of data are used in determining utilization rates for highway accidents; namely, EMS operators' records whenever available or State Highway Safety Department's records whenever the former source of data are not available. For other medical calls and nursing home transfers, EMS operators records are again used when available or, the utilization rates derived by Doeksen et al [21] are employed. The utilization rate for other medical and nursing home transfers is based on nine age groups because such calls are believed to be an increasing function of age distribution. This proposition is strongly supported by several EMS studies in the state.

For the sake of convenience, a unit of demand area is defined to be an area bounded by the standardized township lines of every county. This unit is a thirty-six square mile area (six miles by six miles). The distribution of population by township was determined by counting the most current inventory of resident houses in each township. Engineering maps prepared by the Oklahoma State Department of Transportation were used for this purpose.

The second step was to determine optimum location for EMS systems using a special algorithm referred as Generalized Location Optimization Selection System (GLOSS). This algorithm is based on the general transportation procedure and is set up to minimize a linear objective function of total cost subject to linear constraints. Best location(s) for basic ambulance(s), first responder systems and advanced life support systems of multiple origins are determined at the community and regional level. The program is also used to delineate geographical area of primary response. In other words, the question of which EMS system should have primary responsibility to which demand location is answered by using the objective function of minimizing cost subject to constraints. The cost matrix is developed by determining the distance from an EMS location to the center of each service location following the path of a highway route, gravel or paved road. The distribution of calls determined in step one is combined with the cost matrix to solve the transportaion problem.

The third step involves the use of the results in step two to analyze cost and revenue of alternative EMS systems. This is based on a computerized model that analyzes the economic feasibility of a given rural EMS [31]. Using this model, a budget analysis was made for a one county EMS system analyzing costs and returns under four alternative systems. The procedure can easily be duplicated for any other EMS system.

Finally, a queueing model is suggested to provide information on the probability that an EMS system will be adequate to meet most emergencies.

Findings, Conclusions and Implications

Specific results of this analysis include (1) projected EMS calls for 75 counties of Oklahoma (excluding Oklahoma and Tulsa Counties) for selected years between 1980-1990; (2) best location strategies for basic ambulance, basic life support systems, advanced life support systems and first-responder system both at a county and regional level; and (3) delineation of which area should be served by which EMS system at the lowest cost (this includes estimates of the lowest maximum distance and the lowest average distance an EMS should travel). The cost-revenue model illustrated alternative choices of providing EMS. Because of low intensity of demand in many rural areas, the revenue generating capacity from such calls is not adequate. Alternative sources of funds are needed. Alternatives such as State Amendment 522 are considered. This amendment, known as the Emergency Medical Services Districts Act provides for the formation of EMS districts, which may encompass a county, a group of counties, or school district and assess not more than three (3) mills ad valorem tax for the purpose of providing funds for support, organization, operation of and maintainance of district ambulance services [21].

The results of the queueing model showed that EMS systems in many rural areas have very low intensity implying a high percentage of idle time. An important conclusion from this analysis is that, given limited funds, decisionmakers of either large or small EMS systems must always weigh the trade-off between spending additional funds (purchasing additional emergency units) and the benefits received from these funds (reducing the number of multiple calls). Serious decision problems do arise when the percentage of busy period gets larger and larger. Hence, prior information based on objective analysis can save unnecessary expense.

In general, sharing of services among counties and communities can increase efficiency and effectiveness. Therefore, community leaders, EMS firms and others involved in EMS system planning need to consider EMS service areas when planning EMS districts.

The analytical procedures developed here can be valuable in resolving problems of public and private service delivery systems. They have also the additional advantage of adoptability. Since the purpose of an EMS system is to create a coordinated response to the immediate needs of emergency patients, its planners are expected to consider and provide such coordinated working relationship with hospitals, other public service agencies and the like.

Limitations and Further Research Needs

One of the most important steps used in estimating EMS calls is the population projection model. The model relies on data concerning age-sex specific initial population, birth rates, death rates and net migration rates. The coefficients of birth and death rates are obtained from the State Health Department and are built into the interactive computer program. The operator of this program is required to submit the initial age-sex specific population data and the net migration rates for every area under consideration. From experience, the model seems to be very sensitive to changes in migration rates. This suggests that one must be very careful in determining these values.

In the determination and projection of current and future EMS calls, it was explicitly assumed that the number of EMS calls is directly proportional to the size and/or distribution of population of a given area. This may be too simplistic an approach even though not unreasonable. Other factors such as price of a service, price of alternative services, income of individual patients and other socio-economic variables are implicitly assumed to be invariant against the usage of emergency medical services. Even though this may not be a serious limitation, it may be useful to explore the relevance of such factors empirically.

The effects of changes in the distribution of utilization on the currently determined EMS locations for the basic life support system has not been considered. This is to suggest that research effort on the stability of optimal locations could be valuable.

The state-wide location analysis in this study dealt only with one type of EMS system, i.e. basic life support system (BLS). An extension of this analysis to include first reponder system and advanced life support system could prove to be an important research problem.

The use of the probalistic model may be hampered by the low level of intensity of usage in the rural area. However, periodic analysis of EMS operators' records using the queueing procedure presented could be useful in making decisions concerning new EMS facilities or hiring additional EMS crew. Such decision problems do arise because the probability of a busy period can vary with time.

Another major constraint in EMS system analysis is the availability of pertinent data for predicting and explaining EMS supply and demand. Good record keeping and reporting by EMS firms should always be encouraged so that some sort of data bank could be established. This can imporve the quality of research on problems of medical service systems.

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APPENDIXES

APPENDIX A

TABLE

TABLE XXII

NUMBER OF PERSONS PER HOUSEHOLD BY COUNTY

State of Oklahoma	2.62
Adair	2.99
Alfalfa	2.38
Atoka	2.73
Beaver	2.67
Bechkah	2.53
Blaine	2.59
Bryan	2.54
Caddo	2.72
Canadian	2.95
Carter	2.62
Cherokee	2.73
Choctaw	2.67
Cimmaron	2.62
Cleveland	2.73
Coal	2.66
Comanche	2.87
Cotton	2.56
Craig	2.59
Creek	2.80
Custer	2.55
Delaware	2.69
Dewey	2.59
Ellis	2.50
Garfield	2.55
Garvin	2.55
Grady	2.71
Grant	2.41
Greer	2.29
Harmon	2.47
Harper	2.44
Haskell	2.61
Hughes	2.53
Jackson	2.77
Jefferson	2.53
Johnston	2.61
Kay	2.51
Kingfisher	2.72
Kiowa	2.48
Latimer	2.71
LeFlore	2.75
Lincoln	2.73
Logan	2.70
Love	2.64
McClain	2.84

TABLE XXII (Continued)

State of Oklahoma	2.62
McCurtain	2.89
McIntosh	2.56
Major	2.65
Marshall	2.49
Mayes	2.72
Murray	2.57
Muskogee	2.64
Noble	2.60
Nowata	2.61
Okfuskee	2.62
Okmulgee	2.61
Osage	2.68
Ottawa	2.57
Pawnee	2.65
Payne	2.40
Pittsburg	2.57
Pontotoc	2.54
Pottawatomie	2.67
Pushmataha	2.67
Roger Mills	2.69
Rogers	2.94
Seminole	2.65
Sequoyah	2.90
Stevens	2.59
Texas	2.74
Tillman	2.58
Wagoner	3.02
Washington	2.53
Washita	2.64
Woods	2.33
Woodward	2.73

Source: Population and Households by State and Counties, 1980. U. S. Department of Commerce. Bureau of Census Supplementary Report PC80-51-2

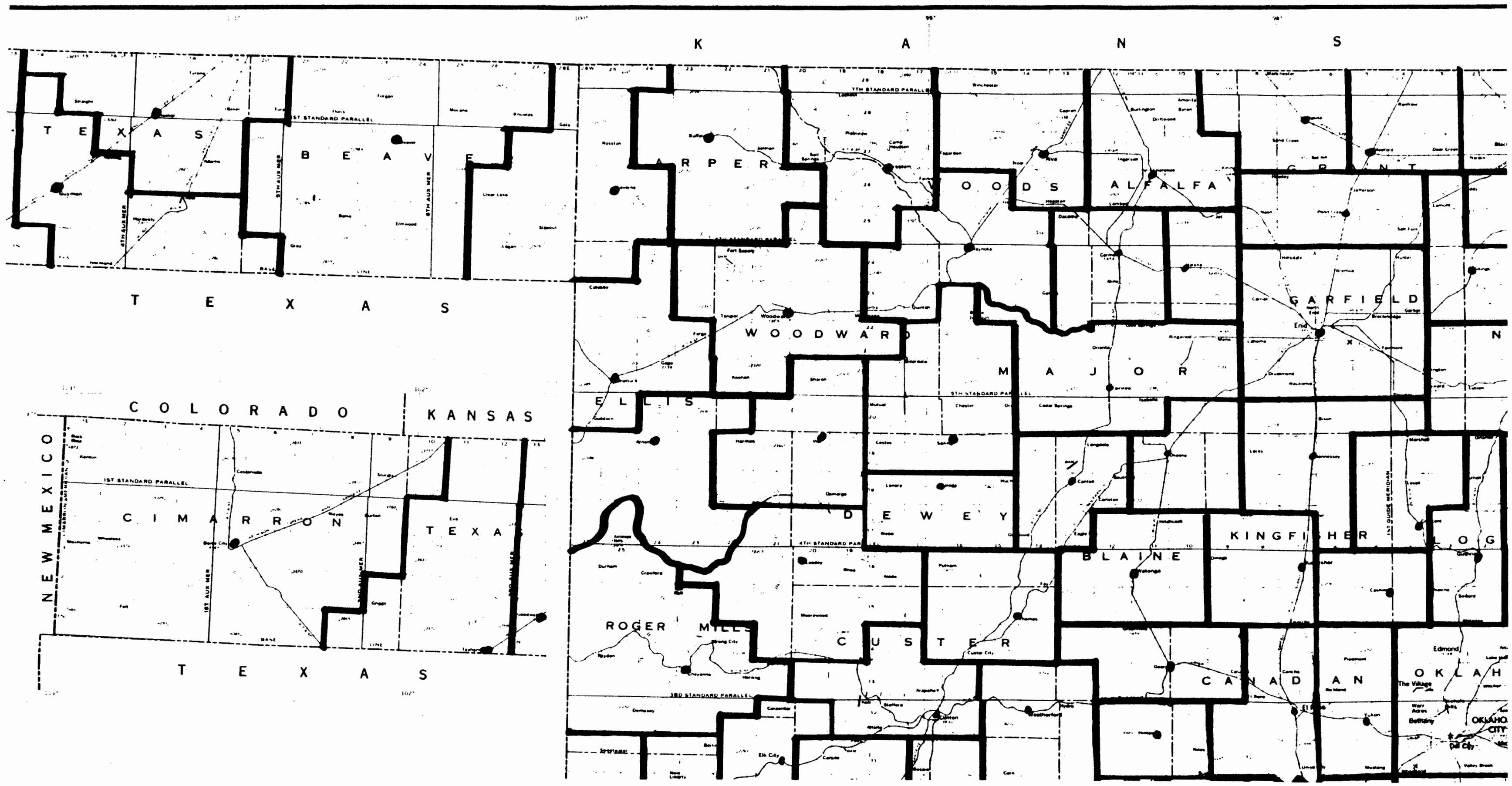
APPENDIX B

DESIGNATED SERVICE AREAS

FOR BASIC LIFE SUPPORT

SYSTEM (BLS) FOR THE

STATE OF OKLAHOMA


K A N S
T E X A S
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C O L O R A D O
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N E W M E X I C O
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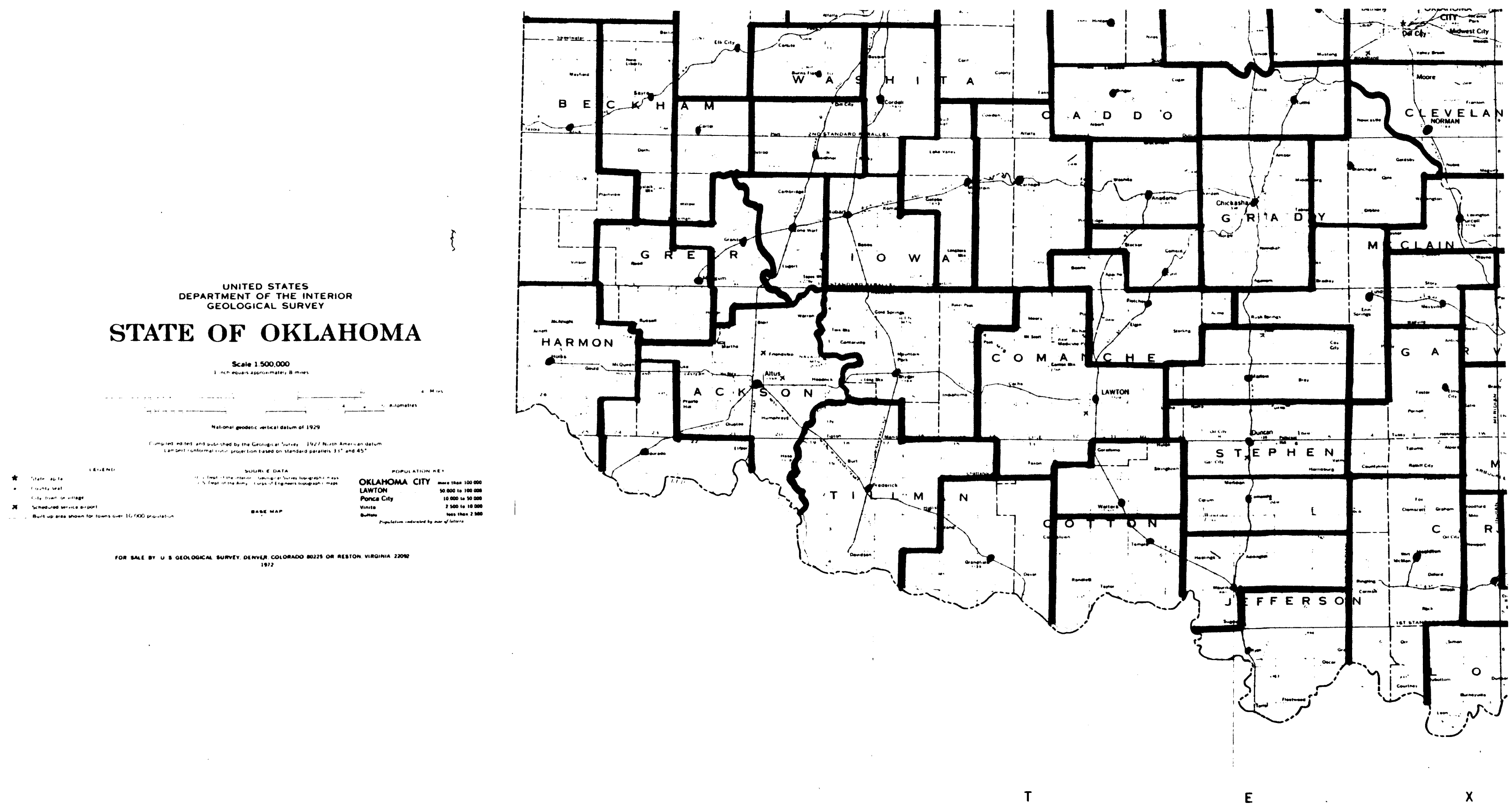
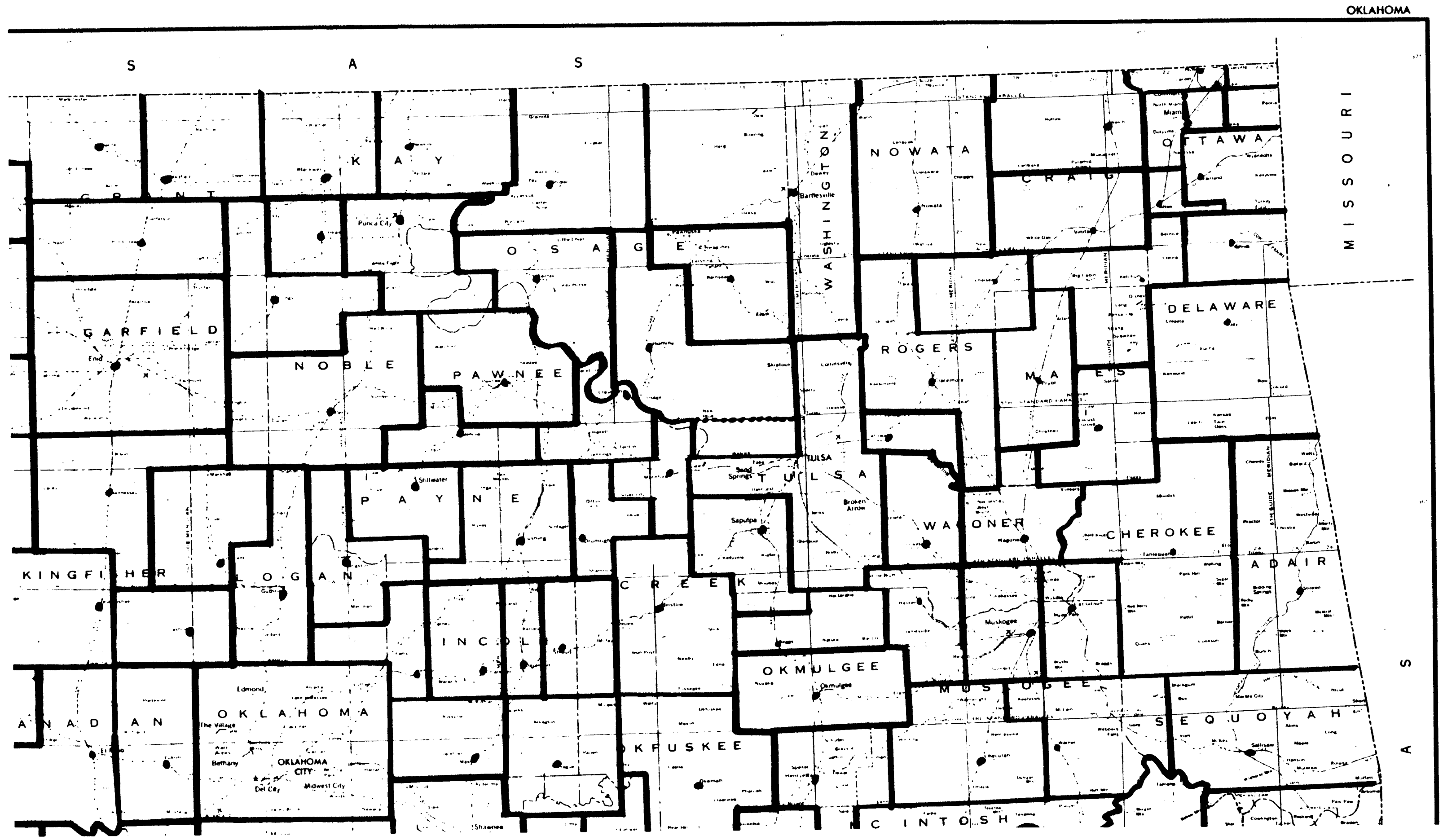
T E X A
T E X A S
A R P E R
W O O D S
A L F A L F A
G A R F I E L D
W O O D W A R
M A J O R
E L L I S
D E W E Y
K I N G F I H E R
B L A I N E
R O G E R M I L L
C U S T E R
C A N A D A N
O K L A H
Enid
Edmond
The Village
Bethany
OKLAHO CITY


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
STATE OF OKLAHOMA
Scale 1:500,000
1 inch equals approximately 8 miles
National geodetic vertical datum of 1929
Compiled, edited, and published by the Geological Survey 1927 North American datum
Lambert conformal conic projection based on standard parallels 33° and 45°
LEGEND
State capital
County seat
City, town or village
Scheduled service airport
Built up area shown for towns over 10,000 population
SOURCE DATA
BASE MAP
POPULATION KEY
OKLAHOMA CITY more than 100 000
LAWTON 50,000 to 100 000
Ponca City 10,000 to 50 000
Vinita 2 500 to 10,000
Buffalo less than 2 500
Population indicated by size of letters
FOR SALE BY U S GEOLOGICAL SURVEY, DENVER, COLORADO 80225 OR RESTON, VIRGINIA 22092
1972
BECKHAM
WASHITA
CADDO
CLEVELAN
NORMAN
Moore
GREER
KIOWA
GRADY
Chickasha
Anadarko
HARMON
JACKSON
Altus
COMANCHE
LAWTON
TILLMAN
COTTON
STEPHEN
Duncan
JEFFERSON
T E X


OKLAHOMA
KAY
OSAGE
WASHINGTON
NOWATA
CRAIG
OTTAWA
MISSOURI
GARFIELD
NOBLE
PAWNEE
ROGERS
DELAWARE
TULSA
PAYNE
CHEROKEE
ADAIR
LOGAN
CREEK
OKMULGEE
OKLAHOMA
SEQUOYAH
Ponca City
Enid
Bartlesville
Stillwater
TULSA
Sand Springs
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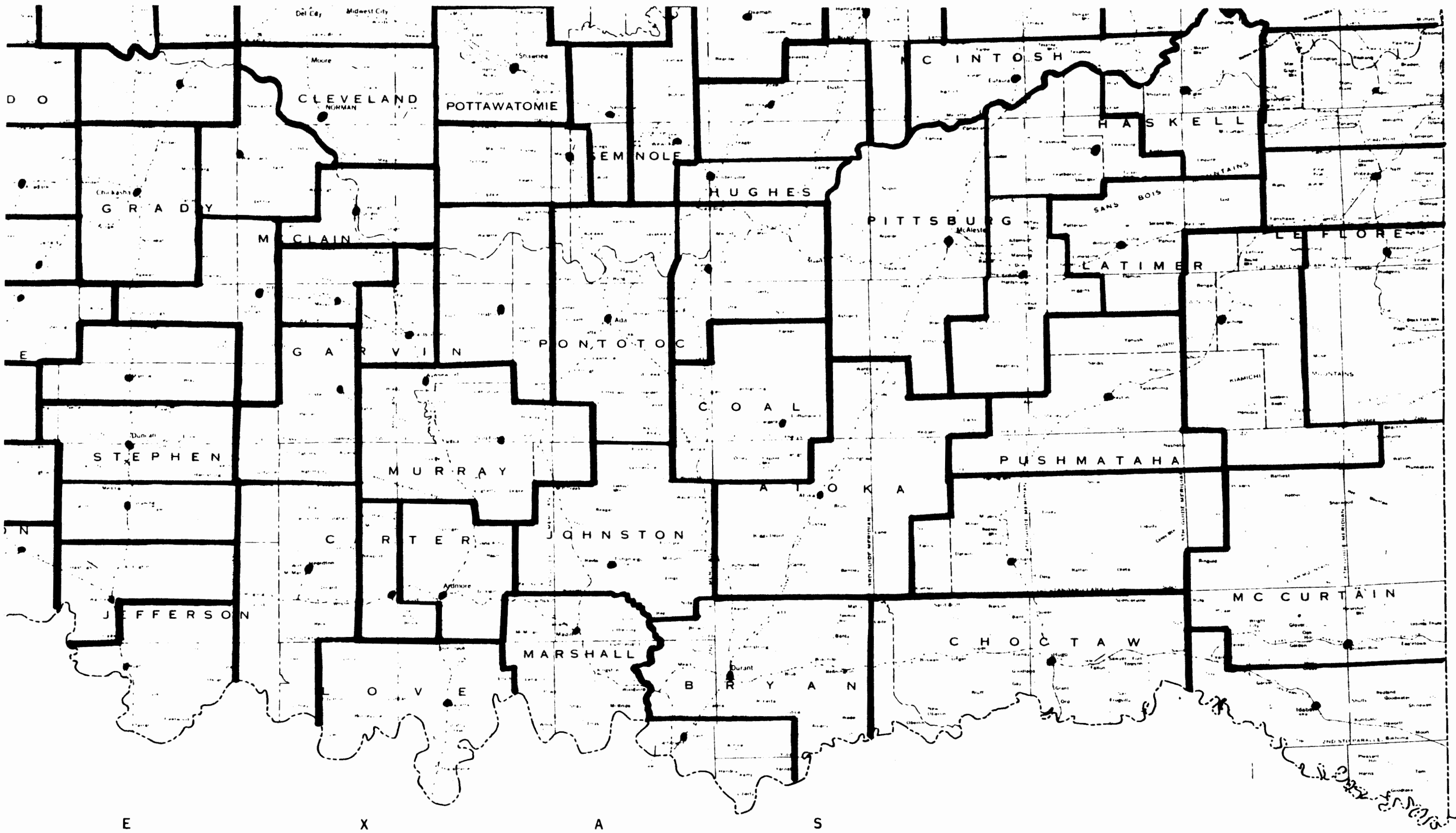
Muskogee
Okmulgee
Edmond
The Village
Bethany
OKLAHOMA CITY
Del City
Midwest City
Shawnee


Del City
Midwest City
Moore
CLEVELAND
NORMAN
POTTAWATOMIE
Shawnee
SEMINOLE
MC INTOSH
HASKELL
GRADY
Chickasha
MC CLAIN
HUGHES
PITTSBURG
McAlester
SANS BOIS
LATIMER
LE FLORE
GARVIN
PONTOTOC
Ada
COAL
STEPHEN
Duncan
MURRAY
PUSHMATAHA
ATOKA
CARTER
JOHNSTON
Ardmore
JEFFERSON
MARSHALL
MC CURTAIN
CHOCTAW
LOVE
BRYAN
Durant
TEXAS
ARKANSAS

2

VITA

Haile-Mariam Gebre-Selassie

Candidate for the Degree of

Doctor of Philosophy

Thesis: ECONOMIC ANALYSIS OF CURRENT AND FUTURE NEEDS OF EMERGENCY MEDICAL SERVICES IN THE STATE OF OKLAHOMA

Major Field: Agricultural Economics

Biographical:

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