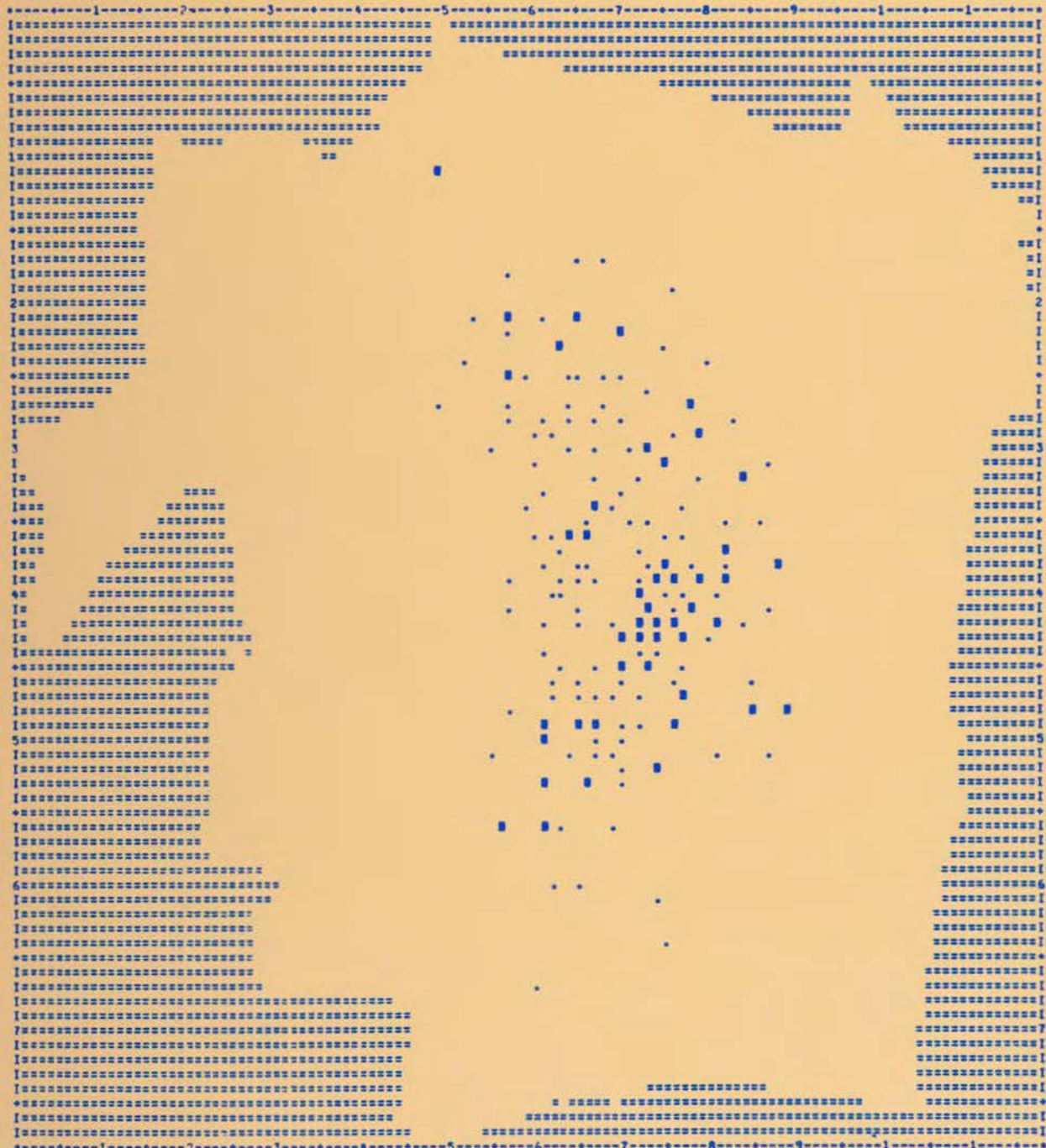


# Analysis of Emergency Medical Services in Austin, Texas

## Volume II: Analytical Methods





Lyndon B. Johnson School of Public Affairs  
Policy Research Project Report  
Number 41

# Analysis of Emergency Medical Services in Austin, Texas

## Volume II Analytical Methods

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**Front Cover:**

The illustration is a computer generated map of the total number of calls for EMS service, as received from each of 358 serial zones in the City of Austin during a five-month period of 1977-1978. Calls are depicted as weights at serial zone centroids. The symbols ( ), ●, and ■ indicate 0 to 10, 11 to 25, and over 25 calls, respectively.



# Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the nine-month policy research project, in the course of which two or three faculty members from different disciplines direct the research of ten to twenty graduate students of diverse backgrounds on a policy issue of concern to an agency of government. This "client orientation" brings the students face to face with administrators, legislators, and other officials active in the policy process, and demonstrates that research in a policy environment demands special talents. It also illuminates the occasional difficulties of relating research findings to the world of political realities.

This report was produced by a policy research project in the academic year 1979-80. The study, funded by the City of Austin, the Texas Department of Human Resources, the

Henry J. Kaiser Family Foundation, and the Lyndon Baines Johnson Foundation, has developed a series of techniques to assist the City of Austin to deploy and manage emergency medical service vehicles. This volume presents user's manuals for four computer packages used by the EMS Policy Research Project in its analysis of emergency medical services in Austin.

It is the intention of the LBJ School both to develop men and women with the capacity to perform effectively in public service and to produce research which will enlighten and inform those already engaged in the policy process. The project which resulted in this volume has helped to accomplish the former; it is our hope and expectation that the report itself will contribute to the latter.

Elspeth Rostow  
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# Chapter 1

## The Use of Mathematical Methods for Analyzing the EMS System in Austin, Texas

There is an appropriate time and setting for systems analyses and computer studies in public policy decision-making. Mathematical modeling can be used to represent relationships between different factors operating in certain situations. If problems include many variables or relationships and if large amounts of data are involved, computers can efficiently do required calculations to suggest policy options. This chapter outlines the role that quantitative methods played in the selection of emergency medical service (EMS) vehicle sites for Austin, Texas. These quantitative methods include a data aggregation program called Call History Analysis Package (CHAP), computer mapping programs, and the GAS and CALL/CZSR analytic location models. This section also discusses several types of location problems, procedures for model selection, and tests of model performance. The utilization of various programs is described in detail in the computer manual chapters that follow.

It should be noted that to review, rank, or evaluate all models that could be applied to an EMS setting is beyond the scope of this chapter. Our goal here is to record the reasons we have chosen to use specific methods and to assess their use in evaluating deployment alternatives for EMS vehicles in Austin.

### THE FACILITY LOCATION PROBLEM

The problem of determining an optimal site for a facility is an old and common one. Private sector analysts have attempted to determine good sites for factories or warehouses since the turn of the century. The prime consideration in this type of facility location has been the minimization of operating and/or construction costs. A factory may be sited to minimize the transport costs of raw materials and labor, or to minimize product distribution costs (1).

A great deal of public facility location research related to emergency facilities for fire, police, and emergency medical services has appeared in the past two decades. Rather than seek locations solely on the basis of reducing costs, public sector planners have been concerned with both cost reduction and the maximization of some measure of societal benefits (2).

Over the past ten years, information gathered from these public sector analyses has been applied to emergency medical service (EMS) systems. There are several definitions of "the EMS problem," and each definition suggests its own method of solution. One approach is to maximize the number of calls served by a system within a specified response

time period using a limited number of vehicles. An alternate formulation seeks to minimize the number of facilities needed to cover all calls (or the service area) within a response time period. A third approach minimizes some measure of response time, such as the mean response time to all calls in the system or perhaps the maximum response time to any call.

Other objectives may enter into consideration in EMS modeling, though they may not be of primary importance. An effective system might include balanced (nearly equal) workloads for each service vehicle. Another objective could be to maximize areas of multiple coverage by EMS vehicles. A modeler may wish to maximize coverage of a particular area identified as a source of EMS demand.

In modeling an EMS system, certain assumptions are commonly made to quantitatively represent the actual system. Often an EMS system is described as a network of nodes and links. The nodes are demand sources or base points for demand distributions; the links represent travel paths. The demand for emergency medical service is represented by a demand surrogate, such as a historical measure of need for service. Vehicle response time is a function of the travel time along the internodal links. Many models assume interchangeability among EMS vehicles and among vehicle personnel. Some approaches allow for explicit modelling of busy vehicles; however, models differ regarding the approach to vehicle availability. Recent interest in multitiered EMS systems has resulted in attempts to model two different levels of service with various types of vehicles.

One recent review discussed two families of locational methodologies, spatial analysis and random process models (3). The random process model is primarily concerned with simulation of EMS operations given station locations. Spatial analysis approaches determine EMS vehicle locations given characteristics of a service area.

Spatial analysis models are often subdivided into deterministic and stochastic models. A deterministic model is generally based on a linear or integer programming formulation, and will often locate facilities to optimize single or multiple objectives. A network is explicitly involved in such a formulation. Stochastic models are usually also based on a network representation of travel and use probabilistic and queuing theory techniques to analyze the system. This chapter refers primarily to spatial analysis approaches.

Heuristic techniques, or procedures that yield good but not necessarily "optimal" solutions, are frequently used to solve spatial analysis problems. The advantage of heuristic procedures is that they may enable analysts to solve large-

scale problems; such models often require less computer core storage, CPU time, or file space than do price optimization approaches. These savings generally result from less

exhaustive search procedures or the use of approximations.

Table 1.1 lists four common spatial analysis models, along with related objectives.

**Table 1.1**  
**Several Location Models**

<i>Model</i>	<i>Objective</i>
Set Covering	Minimize the number of facilities needed to cover the service area (i.e., all demand) within a particular response time
Maximal Covering	Maximize the demand (or area) covered by a given number of facilities within a particular response time
p-Center	Minimize the maximum weighted travel time from a set of p facilities to all nodes
p-Median	Minimize the weighted average travel times from the nearest of p facilities to all nodes

Several problems arise in most deterministic attempts to model an EMS system. Determining the "goodness" of a solution can be a problem. The "best" solution generated by one technique may be inferior to a solution produced by another procedure. This may occur for one of three reasons. First, one procedure may always produce results that are no better than those produced by an alternate solution technique using the same objective(s). Second, one heuristic may produce inferior results for a particular data set when compared with another approach to solving the same problem. Third, the set of sites that is best for one objective may not be as good as an alternate set of sites for a different objective. This third common situation warrants the most careful consideration by the policy analyst. The possibilities indicate that it is desirable to verify results using alternate models.

Differences will exist between the real system and the idealized system. For example, it is difficult to estimate the travel time between any two points on a system because that travel time is not constant in real life. There are large temporal variations on a road network in traffic volumes, which affect the response times of emergency vehicles. The "need" for EMS service is also difficult to estimate because one cannot define true EMS demand. Historical data are but surrogates for future demand patterns.

Another facet of response which is rarely addressed in models is the delay between the onset of a medical incident and the moment of vehicle dispatch. This call processing delay can be important in interpreting model results.

#### DEVELOPMENT OF INPUT DATA

Facility location models require information relating to service demands as input to determine optimal locations. In EMS location problems, historical call data are commonly used as the demand surrogate. To undertake a location analysis, EMS Policy Research Project members perceived the need to develop procedures that could aggregate and array historical call data. To meet this requirement the Call History Analysis Package (CHAP) and various computer mapping programs were developed and utilized. Both are described below.

##### Call History Analysis Package (CHAP)

The Call History Analysis Package (CHAP) was developed by Professor Mark Daskin and Mr. Edmund Stern. This program is a collection of routines that aggregate and array data in ways determined by the user. It generates information on the spatial and temporal patterns as well as



the nature of emergency medical calls, as a means of estimating demand for EMS. This information may be analyzed separately, or it may be used as input to another program.

The CHAP program is actually a collection of four separate computer programs that analyze records of the location and nature of calls for EMS assistance and the responses of the EMS vehicle to these calls. One program, the Call Analysis Program (CAP), can be used to aggregate call data by EMS vehicle, dispatch zones, types of calls, time intervals during which the call occurred, whether the patient was transported or not, as well as other descriptions of calls. All or only a part of the recorded call data may be analyzed.

A second program, the Response Analysis Program (RAP), calculates both the relative and cumulative frequencies of response times, vehicle on-scene times, transport times to the hospital, and the length of time vehicles spend at the hospital, for any user-supplied periods. The Zonal Aggregation Program (ZAP) calculates both the relative and absolute frequencies of calls for geographical locations. It too can analyze selected portions of the data base. The fourth program, which generates additional data (GAP), is used only when additional data are to be added.

Figure 1.1 illustrates the data required for the execution of CAP, RAP, and ZAP, as well as the output data generated by these programs. The figure also summarizes how this information can be used in analysis.

### COMPUTER MAPPING PROGRAMS

Relationships between economic, demographic, or health variables may not be evident when data are represented in tabular or matrix form. SYMAP, SYMVU, and CALFORM are three computer programs that generate pictorial representations of these data in the form of computer maps. The programs produce three types of maps: contour, conformant, and proximal. A contour map is a series of closed curves known as contour lines which connect all points having the same numerical value. Contour maps can be used to display such continuous information as population density and age distributions. In a conformant map, a discrete data value is allocated to each specific bounded region; an example would be a city map indicating population by census tract. In a proximal map, the data points themselves define the map. Zone boundaries are created by the computer, equidistant from adjacent points to which data values have been assigned. A proximal map can be used to depict the primary service area covered by a particular EMS vehicle base.

SYMAP can be used to plot any of the three types of maps via a standard remote job entry terminal printer. SYMVU uses SYMAP data and a pen plotter to produce three-dimensional oblique view contour, conformant, or

proximal maps. The third mapping program, CALFORM, uses a pen plotter to create two-dimensional conformant maps.

### DETERMINING WHICH LOCATION MODEL TO USE

Many factors are involved in selecting analytical methods for evaluating emergency medical systems. A model user must identify the "real" problem while recognizing that formulation, as reflected in the model, influences the perception of the "real" problem. In addition, factors such as model availability and the quantity and quality of data representation affect model selection. For example, a model to minimize response time is not appropriate unless records or estimates exist regarding vehicle response times.

Another factor to consider in model selection is the ease of model use. Ease of use entails several considerations. First, a model should be readily available, considering the time constraints to which most "real world" analyses are subject. Next, the model should be easy to run. If the model requires computer computations, adequate computer facilities must be available. In addition, model results must be easily interpreted. Most EMS models are sophisticated and require the assistance of personnel trained in their use.

The costs of a model also warrant consideration. A potential user will want to know whether a program must be purchased from a vendor and whether it is expensive to use. Most EMS problems are sufficiently complex that multiple executions of the model are required to produce a satisfactory result. Thus, even though the cost of each execution (or "run") may be small, the cost of one hundred executions could significantly affect a project budget.

A final criterion in model selection is its purpose. A model designed only to generate statistical information about competing EMS site configurations may not be an ideal approach for selecting EMS vehicle locations.

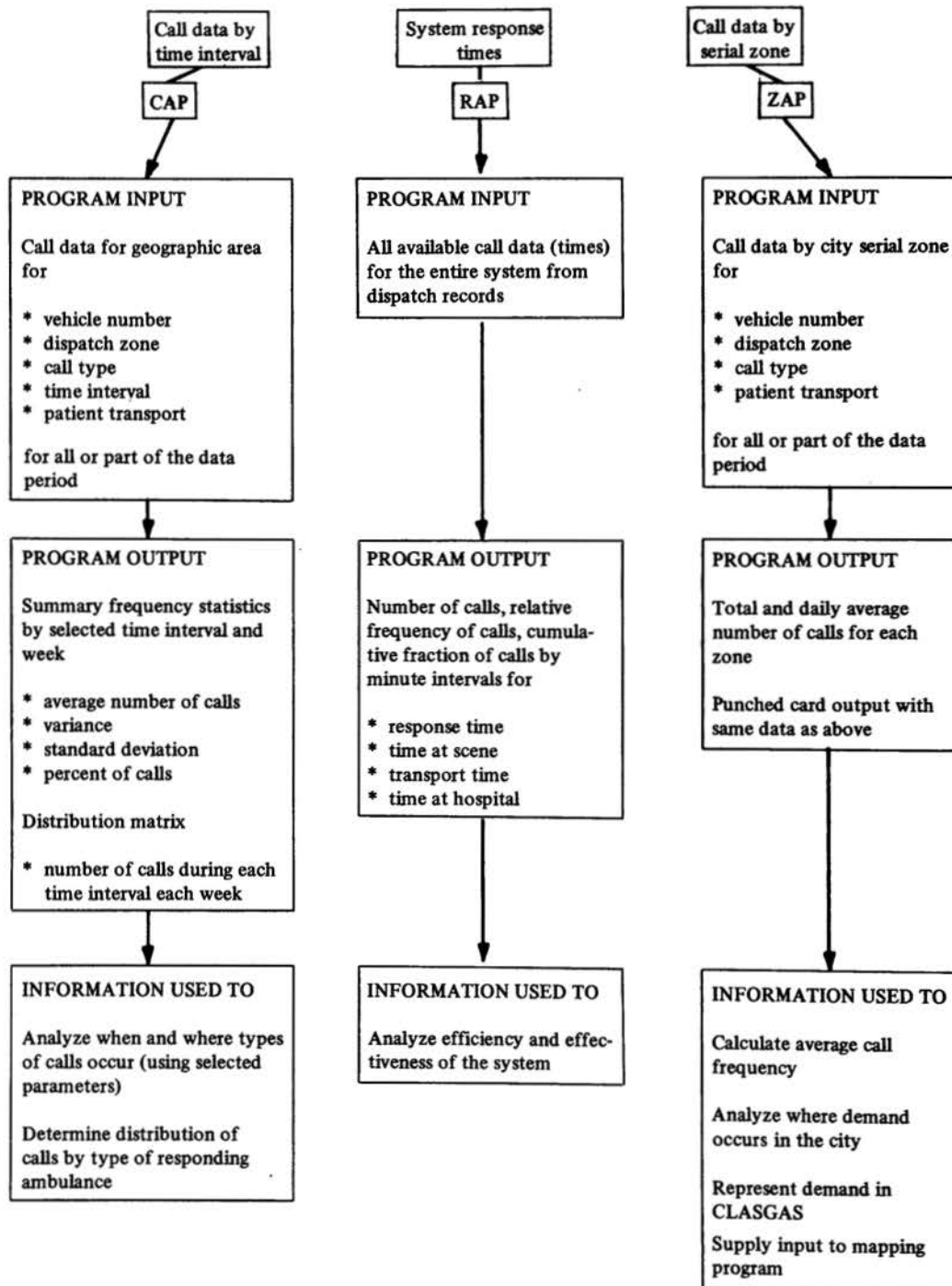
The two models used in the Austin EMS study were (a) the GAS model, which consists of two heuristic algorithms that maximize coverage, and (b) the CALL/CZSR model, another heuristic, whose objective is the minimization of average system response time. These models were chosen based on the various selection criteria.

The primary factor in selecting these models was the availability of the models and personnel skilled in their use. The CALL/CZSR model was created by Professor James A. Fitzsimmons (4) to analyze EMS service in Los Angeles, California. The GAS program was developed by Professor Richard Church of the University of Tennessee (5). Both individuals served as consultants to this study.

A second consideration was that these models could provide insights into the relative performance of the Austin EMS system and could suggest better vehicle site configurations. Third, these models could be executed on The Uni-

**Figure 1.1**  
**CHAP Flow Chart**

**USER REQUIREMENT TO ANALYZE**



versity of Texas at Austin computer system; other models considered for use require more computer storage space than exists on The University of Texas computer. Finally, the data available to the study members were adequate for running both GAS and CALL/CZSR.

Three types of data are required by these models: a matrix of travel times, historical call data, and population data. The travel time "matrix" is an estimate of the expected vehicle travel time from any serial zone in Austin to every other serial zone. The matrix of travel times used in this study was based on a joint Austin Transportation Study Office and Texas Highway Department study completed in 1977 (6). Call data, used to represent EMS demand, were recorded by Austin EMS dispatchers for December 1976, and January, June, July, and August 1977. The record for each call included both temporal and spatial information (7). Population and housing data, used to determine the nature of EMS demand, were adapted from the 1976 Special Census of Travis County, Texas, conducted by the U.S. Department of Commerce, Bureau of the Census (8).

### Performance of the Models

After extensive use of these methods, it is possible to assess both their strengths and weaknesses in representing the EMS vehicle siting problem in Austin, and the quality and cost of their results.

CALL/CZSR is a heuristic for solving a p-median type problem. GAS is a procedure designed to solve the maximal covering problem. Although each attempts to model some of the features of an EMS system, each has shortcomings.

The CALL/CZSR model seeks to minimize the average response time of a system of EMS vehicles, taking into account the probability of vehicles being busy. It does this by searching zones contiguous to user-defined initial vehicle locations and attempting to reduce response times for the entire system. It continues the search until some upper limit on iterations is reached or until the improvement in response time is less than some limit (9).

The GAS model consists of two algorithms, GA and GAS, both of which solve the maximal covering location problem. The GA (Greedy Adding) algorithm starts with no sites selected and locates vehicles one at a time at the facility sites that maximize call or demand coverage. The best facility site at any point in the algorithm is defined to be that site which covers at least as much of the uncovered demand as any other site. The GAS (Greedy Adding with Substitution) algorithm differs from GA only in its ability to substitute for previously located sites that are no longer justified.

Both GAS and CALL/CZSR programs provide information about (a) the percentage of calls that can be reached

by any given vehicle site configuration, and (b) statistics about individual vehicle and system performance. Both list the service areas of vehicles and the sites that should respond to calls made from particular zones.

Neither GAS nor CALL/CZSR fully addresses the problem of covering areas of demand left uncovered when vehicles are busy—the problem of real-time vehicle deployment. For example, consider an EMS system with two vehicles operating from separate facility sites. When one vehicle is busy, the other vehicle must respond to the next call, whether it be in that vehicle's primary service area or in the area served by the other vehicle. While the idle vehicle may have been optimally located to cover its own demand area, its location is probably not optimal for covering both its own area and the area covered by the other, busy vehicle. Although CALL/CZSR does take a simulated pattern of calls and busy vehicles into its siting considerations, it does not simulate real-time control strategies. Both simulation and optimization models could be developed to deal with this EMS operating problem.

One problem with evaluating the results of both models is that the outputs are limited by the quality of the input data. The travel time projections are based on assumptions regarding the nature of vehicular travel and the rationale behind driver decisions. For example, the time estimates reflect a hypothetical structure for the city of Austin in 1995; many uncertainties surround such estimates of travel time over a metropolitan area. Call data from 1976-1977 may or may not reflect the pattern of future calls. Patient tracer data, describing the patient status, would have been useful for verifying the effectiveness of the EMS system; these data were not available. In addition, the call data were recorded in whole minutes. This logging procedure may have caused errors in our response time calculations. The volume of data—4,331 calls collected over five months—was large enough to provide some consistency, but not sufficiently large to insure statistical accuracy for long-term projections.

The population and housing information from the 1976 Special Census of Travis County was accumulated by census blocks, small homogeneous areas including tens or hundreds of persons. These data had to be aggregated to the same geographical units as the other data, to transportation serial zones. The data translation process may slightly distort the census information.

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## Chapter 2

# A Manual for Users of the CHAP Program

An EMS system is a collection of vehicles, persons, and equipment that provide medical assistance and transportation in emergencies. One early stage of EMS planning should be the evaluation of the place, time, pattern, and nature of emergency events. Members of the Austin EMS study team have developed four computer programs called CHAP (Call History Analysis Package) to aggregate and array historical data.

The primary purpose of this chapter is to discuss the capabilities of CHAP and to illustrate its use in the analysis of EMS call information. Sections in this chapter include information on program capabilities, job control and parameter cards, default values, and output information of each of the four programs as applied to a set of Austin EMS call records.

### OVERVIEW OF CHAP

CHAP is designed to analyze historical call data, the information contained in dispatcher records of all calls received by the Emergency Medical Service Department of the City of Austin. Depending upon the user's interests, any combination of the following four programs may be executed:

- Call Analysis Program (CAP);
- Response Analysis Program (RAP);
- Zonal Aggregation Program (ZAP);
- Generation of Additional Data Program (GAP).

The last program (GAP) allows the user to generate and store three items of information not recorded by the City of Austin for each EMS call: the day and the week during which the call was received, and a code to indicate if the call occurred within a week for which seven complete days of data exist. After this information has been added to the call data, the computer tape which stores the data is rewritten. The user may request output in the form of computer cards, each of which will contain information (including the recent additions) on one EMS call.\* GAP need only be executed when additional data are added to the data set.†

\* Special instructions (not described in this chapter) must be used to generate a new set of computer cards bearing this information.

† GAP is a special purpose routine based on the data available on June 1, 1979. Minor changes to GAP may be required before it is executed using additional EMS call information.

Since GAP is not used to analyze calls, it will not be discussed further.

The other three programs—CAP, RAP and ZAP—generate summary statistics from the historical record of EMS calls. The Call Analysis Program (CAP) aggregates historical call information for each vehicle by geographical location, type of call, dispatch zones, and time interval. The program also lists the data in tabular form. The Response Analysis Program (RAP) permits the user to calculate a historical frequency distribution of system response time to calls, vehicle on-scene time, transport time to hospital, and time at the hospital. The Zonal Aggregation Program (ZAP) can compute and display information on the total number of calls from each city serial zone. ZAP can also generate punch card output.

The CHAP program uses data from incoming EMS calls based upon dispatcher records that are stored on a computer file. The format specification for each computer card image\* is shown in Table 2.1. The time information was obtained from punch-clock records (in whole minutes) of 4,331 incoming calls to EMS recorded in December of 1976 and January, June, July, and August of 1977 (1). The GAP program generated card columns 21 through 24.

Most of the CHAP subroutines are capable of identifying card images with unacceptable values. For example, if the hour of the call in a card image exceeds 23 (e.g., 26th hour of the day), the call data would be flagged as unacceptable. Each subroutine will print a message describing the nature of the error and the card image that caused the erroneous condition to be generated.

The user of EMS call information implicitly makes a number of assumptions concerning its validity, completeness, and consistency. The user must assume that the EMS Department recorded and reported the call data accurately and in a consistent pattern. Another way to say this is to assert that all incoming EMS calls were recorded and that there are no coding errors in the call data. If a user plans to generalize for future EMS policy on the basis of these records, he or she implicitly assumes that future calls will mimic the patterns established in the limited historical record of calls.

\* The original data were punched on computer cards. Data used in analysis are read from files of computer card images.



**Table 2.1**  
**Format Specification for Call Data**

<i>Columns</i>	<i>Definitions</i>
1-4	zone number where call originates
5-6	month of call
7-8	date of call
9-10	time of call, hour (0-23)
11-12	time of call, minutes (0-59) in that hour
13-14	time of arrival on scene, minutes in an hour (0-59)
15-16	time of departure from scene, minutes in an hour (0-59)
17-18	time of arrival at hospital, minutes in an hour (0-59)
19-20	time of departure from hospital, minutes in an hour (0-59)
21*	day of week (1-7, Monday = 1)
22-23*	rank order of the week in which the call occurred
24*	0 (if data exists for the full week in which the call occurs) 1 (if data does not exist for the full week in which the call occurs)
25-26	reference number of dispatched ambulance
27-29	zone from which ambulance was dispatched
30-32	code number for the type of call

\*These data are added by the GAP program.

### Control Cards, Program Selection, and Default Values

To run CHAP, the user needs certain job control cards and various parameter cards. The control cards required to execute the CHAP program are listed in tables in the appendix for both the City of Austin (Table 2.14) and The University of Texas (Table 2.15) computer systems. Table 2.16 lists the card substitutions required to obtain ZAP output in punched card form using The University of Texas computer system.

The first card following the job control cards\* specifies which of the four subroutines in CHAP the user wishes to execute. Table 2.2 indicates the command needed to select each of the four programs. Within a single CHAP run the user can execute any number of analyses by inserting program selection cards along with the appropriate subprogram

\* The cards described below are actually inserted in the job control decks (Tables 2.14 to 2.16) at the location specified by parameter blocks A through K.



**Table 2.2**  
**Parameter Cards for Program Selection**

<i>Variable*</i>	<i>Program Selected</i>
ANALYZE	Call Analysis Program (CAP)
FREQUENCY	Response Analysis Program (RAP)
AGGREGATE	Zonal Aggregation Program (ZAP)
ADD	Generation of Additional Data Program (GAP)

\*Begin to keypunch each of these variables in column one.

parameter cards. For example, if a user wishes to run both CAP and ZAP, the AGGREGATE card can initiate ZAP after the deck of CAP cards. The subprograms may be executed in any order in the CHAP run.

In the event a user does not include certain parameter cards, the CHAP program has been provided with built in "initial" default values (see Table 2.17). CAP and ZAP have provisions to override the initial default values and use "current" default values for subsegment runs. These options are explained in the CAP section dealing with CONTINUE AND RESTART parameter cards.

### THE CALL ANALYSIS PROGRAM (CAP)

CAP computes the relative frequency of EMS calls by user-specified time intervals, geographic areas, incident types, vehicle identification numbers, dispatch zones, temporal portions of the data set, or days of the week. In addition the user can analyze transport calls only, nontransport calls, or all calls. The program will compute frequency counts, averages, variances, standard deviations, and percentages for these specifications.

The options for geographical area include all serial zones of the city, numerical ranges of zones, individual zones, and combinations of numerical ranges and individual zones. The zones used in this study were the 358 serial zones defined by the Austin Transportation Study Office (2). These serial zones approximately aggregate to census tracts and planning areas.

The time interval options included: (a) the months or weeks under analysis (TIME cards); (b) the days under analysis (PERIOD cards); and (c) the hour interval (INTERVAL cards). The first two options are used to select a subset of EMS calls for the analysis. When the user specifies the months or weeks of interest, the beginning and ending

months and dates may be defined on parameter cards. The user can generate relative frequency information for various periods in a week—the full week, particular days of the week, or groups of days. The hour option is used to specify the number of hours (the time interval) into which call events shall be aggregated.

The ambulance option allows the user to study the response for a single EMS vehicle, a group of vehicles, or all the vehicles. The dispatch zone option similarly allows a user to select a single zone for dispatch, a group of zones, or all zones. A maximum of ten specific zones for dispatch or ten specific vehicles can be selected for these parameters.

The Austin EMS Department has assigned each EMS response to one of eleven incident types. For example, "GUN" represents those responses where a form of violence occurred (stabbing, shooting, or assault). The user may choose to analyze data for a certain category, a group of categories, or for all types of calls.

The transport/no-transport option allows the user to include all the calls in the data base, include only those EMS vehicle responses which transported patients to the hospital, or include only those which did not transport a patient to a hospital.

### Card Punch Procedures

This section provides information on the various parameter cards that may be used in executing a Call Analysis Program. For ease of identification, each block of parameter cards is designated alphabetically A through K. Table 2.17 lists card punch formats. The following text provides the user with an explanation of the options available with each parameter.

The Program Selection Card, block A, begins the CHAP program deck. The following blocks of cards (through I) may appear in any order. These cards must be followed by blocks J and K in that order.

#### Block A—Program Selection Card

These parameter cards specify which of the four programs in CHAP the user wishes to execute. Table 2.2 (see above) indicates the command needed to select each of the four programs.

#### Block B—Zonal Parameter Cards

Block B specifies the city zones for which call incident data should be aggregated. As many as fourteen parameter cards are required if a user wishes to specify particular zones or numerical ranges of zones. The first parameter card specifies the extent of the geographical area of interest. This area can be the entire city (all city zones), ranges of city zones, or particular zones of the city. If a

user is interested in all city zones, then only one zonal parameter card need be included in the parameter deck; the remaining cards are unnecessary and should be omitted.

A set of cards is necessary to identify either the numerical range of city zones or the individual zones by which the user wishes to aggregate calls for service. The first card identifies the option selected and the following cards identify the zones or ranges of zones. A maximum of five ranges or a maximum of fifty individual zones may be specified when using these options. A final parameter card with the word "END" punched on it signals an end to the geographical specifications for each suboption. It is used whenever numerical ranges of the city zones or individual city zones are specified as part of the geographical area.

A combination of ranges and particular city zones may be analyzed during one run. If the user is interested in specifying an area of this nature, then two sets of block B parameter cards would be required, each of which must be terminated by an END card. One set would describe the range of zones and the other the particular city zones of interest.

#### Block C—Period Parameter Cards

Block C indicates the time period for aggregating EMS calls. If the user wishes to perform an analysis of weekly call data, then only one parameter card is necessary. As many as nine parameter cards can be included in a card deck if a user is interested in analyzing specific days of the week.

The first parameter card specifies whether the whole week or particular days of the week are to be analyzed. The second parameter card or deck of cards is necessary if the first parameter card specifies "DAYS," indicating the desire to analyze calls that occurred on specific days of the week. One day can be punched on each card.

All seven days of the week can be analyzed by either the WEEK or the DAYS option. Although both runs would analyze all seven days of the week, they would produce different numerical results. If the WEEK option is utilized, CAP analyzes call data only for those weeks in which data for all seven days are available. Under this option the number of Mondays is equal to the number of Tuesdays, and so on. If the DAYS option is selected, the program will include a larger number of EMS calls, since the number of Mondays in the data set may differ from the number of Tuesdays, etc. Although the DAYS option includes a larger number of calls, it is not as regular a set of data. Thus, the WEEK option is recommended over the DAYS option for analyzing calls from all seven days of the week.

A final parameter card with the word "END" on it terminates block C information, if the DAYS option is selected. If block C cards are omitted, CAP utilizes the de-

fault value as the period option.

#### Block D—Interval Parameter Cards

The two parameter cards of block D specify the way to subdivide time for aggregating EMS calls. Both cards are required whenever the user specifies an hour interval other than the default value. The word "INTERVAL" is punched on the first parameter card to indicate that the subsequent card contains the interval length. The second parameter card specifies the exact "number of hours" to be used in aggregating the call data. Any integer value from 1 through 24 can be punched on this card. Values of 1, 2, 3, 4, 6, 8, 12, or 24 are recommended.

#### Block E—Time Parameter Card

This block indicates the length of the historical record of EMS calls to be included in the analysis. If the user is interested in call data for a specific range of calendar dates (e.g., some subset of the total historical record), then block E cards are required.

The first parameter card contains the word "TIME," denoting that a specific range will follow. The second parameter card indicates the beginning and end of the period for which call data are to be aggregated. The number of the beginning month must be less than or equal to the number of the ending month. If the initial and final months are the same, then the beginning date must be less than or equal to the ending date.

#### Block F—Type Cards

Block F cards indicate the type of incident to be analyzed. If the user wants to analyze data with all calls included, only one card is required. If specific call types are of interest, three card sets are required. The first card indicates a specific type (or types) will be analyzed; the second set of cards names the type(s). An END card completes the parameter deck.

Eleven different call types have been catalogued in the Austin data set. A user may specify one or more of these types by inserting a card for each type after the first parameter card. An END card must appear at the end of the block of cards. The call type categories are listed in Table 2.3.

#### Block G—EMS Vehicle Card

This block of cards is used to isolate the activity of one or more EMS vehicles. To include all vehicles the user needs only a single card with "AMBULANCE" and "ALL" punched in the correct columns. Two cards are used to isolate the activity of one or more vehicles. The first card indicates that specific ambulances are to be analyzed and the

**Table 2.3**  
**Types of EMS Calls**

<i>Variable</i>	<i>Type of Incident</i>
AUTO	motor vehicle trauma
DRUG	overdose, poison
GUN	stabbing, shooting, assault
ACCIDENT	accidental injuries
HEART	heart attack, breathing difficulty
SEIZURE	seizure, convulsion
STROKES	strokes
BABY	obstetrics, gynecology
HOUSE	domestic illness
UNCON	unconscious person
UNKNOWN	unknown

second card specifies the ambulance numbers. The second card can specify up to ten ambulance numbers.

#### Block H—Dispatch Parameter Card

Block H is used to isolate the performance of vehicles dispatched from specific serial zones. If all dispatch zones are of interest, the user needs only a single card with the words DISPATCH and ALL in the correct columns. To specify certain dispatch zones the user must insert two cards. The first card indicates that one or more dispatch zones will be considered in the analysis and the second card identifies the zones. A maximum of ten zones may be identified. The output will reflect aggregate activity of vehicles dispatched from the identified zones.

#### Block I—Transport Parameter Cards

This parameter allows the user to differentiate between all calls and calls for which a patient was or was not transported to the hospital. A user can analyze all calls by including a single card with "TRANSPORT" and "ALL" punched on it. To select only transported calls for analysis, the user punches a single card with "TRANSPORT" repeated twice in the proper columns. If nontransported cases

are to be analyzed, the card will indicate this with the words "TRANSPORT" and "NOTRANS."

#### Block J—GOMAN Parameter Card

Block J contains one required parameter card which initiates the analysis. It should follow all parameter cards used to describe the analysis. The option "PRINT" specifies that CAP should print the table listing the call frequency for each possible time interval, aggregated over all serial zones in the analysis. The option "NOPRINT" specifies that this table should not be included in the output.

#### Block K—Program Continuation Cards

The block K card allows the user to instruct the computer to execute multiple analyses with a single CAP run. If either "CONTINUE" or "RESTART" appears on a card, an additional analysis is indicated. Only one of these words should be used at a time.

The "CONTINUE" command is used to perform a subsequent analysis which makes only minor modifications to the parameters of the previous run. For example, assume that a user wishes to run two data analyses, one with an aggregation interval of two hours and the other with a four-hour interval. In this case, the CONTINUE command directs CAP to use the most recent parameter values (as "current" default values), rather than the "initial" values built into the program. The only parameter cards required in addition to the CONTINUE card would be the INTERVAL cards and the GOMAN card.

The "RESTART" command is used if a subsequent analysis differs significantly from the previous analysis. In such a case, the initial CHAP default options may be a more convenient set of parameters. For example, imagine that a user seeks information on the number of calls in certain zones for four-hour periods on specific days of the week—with all other parameters the same as the initial default values. In this case, the user would use the RESTART card and add cards specifying the desired time interval, the days, and the zones. The RESTART command will instruct the computer to use the initial default values along with the specified parameters.

If a block of parameter cards is omitted, the initial or current default value will apply, depending on whether the CONTINUE or RESTART cards are used. For example, if a card deck represents the first CAP after the ANALYZE command or if it follows a RESTART command, then the initial default values apply. However, if the run follows a CONTINUE command, the current default options apply. Table 2.17 gives the initial default options for all parameter card sets.

### A Sample Problem

The foregoing discussion has dealt with general procedures and inputs for the Call Analysis Program. To better understand these procedures a sample problem is now provided. This problem will also be used in the following section to illustrate the output of CAP.

The problem is to find the temporal distribution of four incident types in the central business district of Austin using a two-hour time interval. The parameter values are listed in Table 2.4. When the problem's parameters are identical to CHAP's initial default values, no parameter cards are needed.

**Table 2.4**  
**CAP Sample Problem**

<i>Variable</i>	<i>Sample Values</i>
Type call*	GUN, DRUG, ACCIDENT, UNCON
Zones*	1-22, 51-55, 166, 167
Period	week
Hourly interval*	two hours
Time period	all months
Ambulance	all ambulances
Transport/no-transport	all calls
Dispatch zones	any zones
* Indicates that a set of parameter cards would be required in the program deck.	

Figure 2.1 illustrates the general arrangement of card blocks needed to run this sample problem. As this is a Call Analysis Program, the block A card must be punched with the word ANALYZE. The block B, D, and F cards directly follow block A. The first zonal parameter (block B) card specifies that ranges of city zones are to be analyzed. The second through fourth cards specify the ranges—three cards can describe the central business district. An END card completes this block of cards. The type of call (block F) cards follow the zonal cards in this example. The first card, with the words TYPE and SOME, indicates that specific types are to be analyzed. Following this card are four cards, each specifying a type of call. For the sample problem these

are GUN, DRUG, ACCIDENT, and UNCONSCIOUS. An END card completes this block of cards. The third block of cards specifies the interval, which in this case is two hours. The first card has the single word INTERVAL punched on it. The second card defines the interval as two hours. A GOMAN card follows these cards to initiate the analysis. Table 2.19 lists both these cards and the control cards necessary to run the sample analysis on The University of Texas computer system.

### CAP Output Information

Four types of CAP output information for the sample problem are represented in this section. One type of output, shown in Table 2.5, is a set of error summaries. This table lists erroneous incident information that is excluded from the analysis. For example, the circled numbers 8 (first 3 lines) indicate that in three cases the EMS dispatcher reported that vehicle 8 was dispatched; no such vehicle identifier existed at the time. The circled numbers 314, 0, and 16 indicate a report of call type 314, 0, or 16. No such call type exists.

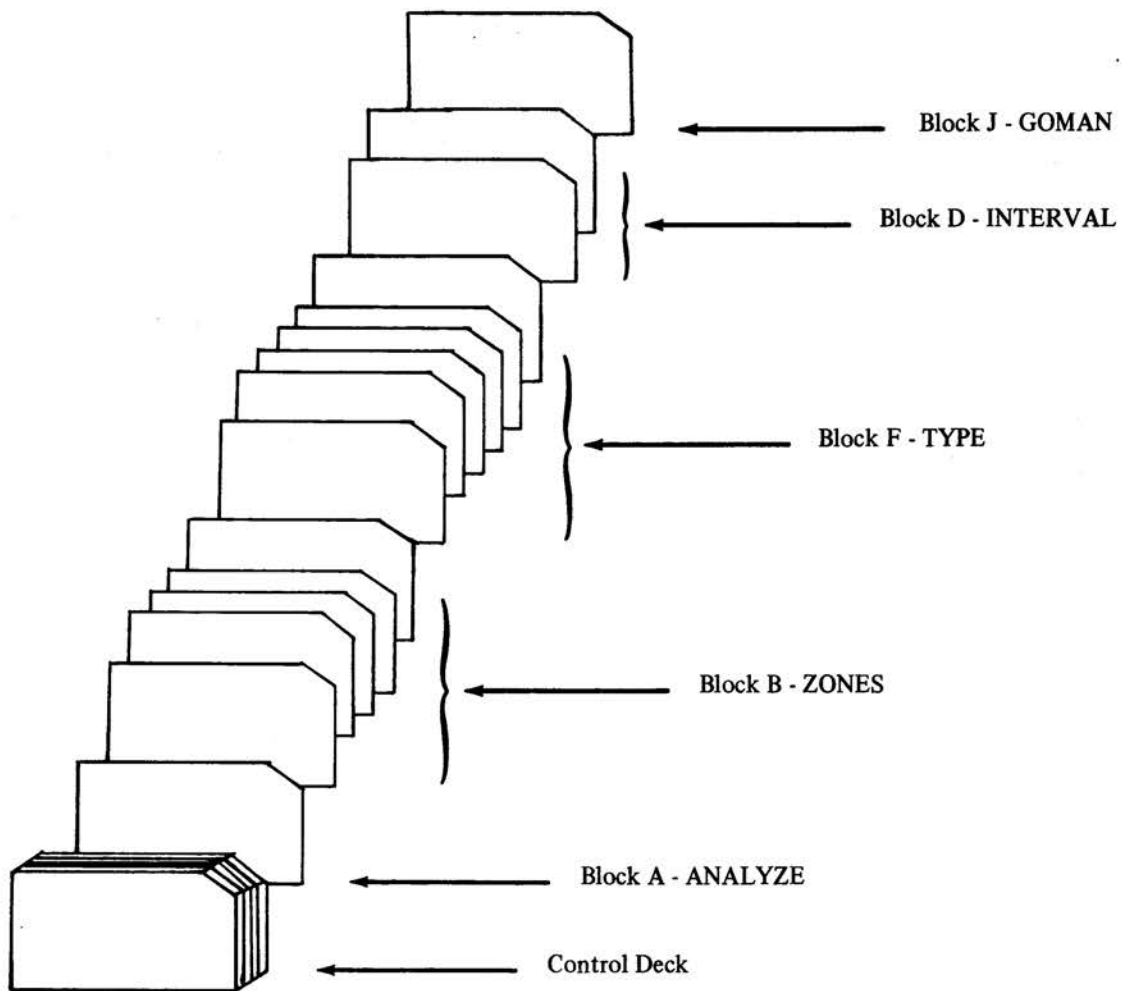
A second output, illustrated in Table 2.6, is a listing of the parameters which have been selected by the user. For the sample problem this information would be identical to Table 2.4. If the DAYS option were used, the circled output information for the DAYS OF THE WEEK would be replaced by the words MONDAY (21), indicating 21 Mondays.

Table 2.7 is a list of summary call frequency statistics for selected time intervals. The first part of the output lists statistics for each day of the week for the selected time interval (only the first two days are shown in Table 2.7). The sample problem specified two-hour intervals; therefore, the underlined row in Table 2.7 represents the eighth interval, or the period from 2 p.m. to 4 p.m. on Monday. The number of specified calls (column 2) for Mondays during this interval in the central business district is 2. The average number of calls (column 3) is 0.1 calls between 2 p.m. and 4 p.m. on Mondays. The variance is 0.09 and the standard deviation is 0.3 calls. Two-and-a-half percent of the calls analyzed in the run occurred during this time interval. The second part of the output lists the same statistics for each week of the period under study. In this example 80 calls occurred during 21 weeks in these districts.

Table 2.8 illustrates a fourth possible output, the call distribution matrix, which is obtained only if the PRINT option appears on the GOMAN card in block J. To illustrate the interpretation of the distribution matrix, imagine that the user wishes to determine the number of these four types of EMS calls made from the central business district between 10 p.m. and 12 p.m. on Monday, during the fourth week of the call data. The information is shown as the



**Figure 2.1**  
**Complete Deck for the Sample Problem**



**Table 2.5**  
**Set of Error Summaries**

+++ZONE+++	162	12	1	11	3	4	16	24	45	3	1	0	8	162	5
AMBULANCE NUMBER EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	75	12	1	15	14	15	23	32	58	3	1	0	8	75	9
AMBULANCE NUMBER EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	76	12	2	23	28	29	30	0	0	4	1	0	8	76	1
AMBULANCE NUMBER EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	314	1	11	9	50	54	5	14	37	2	6	0	3	214	314
TYPE EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	312	6	14	0	0	0	0	0	3	2	11	0	0	0	0
TYPE EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	114	7	20	18	39	45	6	15	2	3	17	0	7	118	16
TYPE EXCEPTION...WARNING...CALL DATA FOLLOW.															
+++ZONE+++	-0	-1	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
MONTH EXCEPTION...WARNING...CALL DATA FOLLOW.															

**Table 2.6**  
**Input Parameters for Sample Problems**

ZONES	FROM	TO
	1	22
	51	55
	166	167
	0	0
	0	0
DAYS OF WEEK	ALL 7 DAYS 21 WEEKS ANALYZED	
INTERVAL WAS	2 HOURS.	
PERIOD WAS	ALL 5 MONTHS	
DISPATCH ZONES WERE	ANY	
AMBULANCE NUMBERS WERE	ALL	
INCIDENT TYPES WERE	DRUG GUN SHOT ACCIDENT UNCONSCIOUS	
TRANSPORT AND NON-TRANSPORT CALLS RECORDED		

circled number "1" in Table 8 under week 4 and across from period 12. Since the two-hour intervals begin at midnight, period 12 represents the 22nd and 23rd hours (between 10 p.m. and 12 p.m.) of the first day in the fourth week.

This output provides the planner with demand information based upon historical data for various sections of the city. For the sample problem, the analysis deals with the central business district. The information provides the planner with a better understanding of the busy periods of the day or week for certain calls of a critical nature. It indicates the sites of greatest demand for EMS vehicles and can aid in the workload planning. The measures of demand calculated by CAP can be used by other programs in the analysis of alternate EMS vehicle sites.

**Table 2.7**  
**Summary Frequency Statistics\***

**I. Statistics for Days of the Week**

INTERVAL	COUNT	AVERAGE	VARIANCE	STD. DEV.	PERCENT
1	2.	.10	.09	.30	2.50
2	0.	0.00	0.00	0.00	0.00
3	0.	0.00	0.00	0.00	0.00
4	0.	0.00	0.00	0.00	0.00
5	0.	0.00	0.00	0.00	0.00
6	0.	0.00	0.00	0.00	0.00
7	0.	0.00	0.00	0.00	0.00
8	2.	.10	.09	.30	2.50
9	1.	.05	.05	.22	1.25
10	3.	.14	.23	.48	3.75
11	0.	0.00	0.00	0.00	0.00
12	4.	.19	.16	.40	5.00
13	1.	.05	.05	.22	1.25
14	2.	.10	.09	.30	2.50
15	0.	0.00	0.00	0.00	0.00
16	1.	.05	.05	.22	1.25
17	1.	.05	.05	.22	1.25
18	2.	.10	.09	.30	2.50
19	0.	0.00	0.00	0.00	0.00
20	2.	.10	.09	.30	2.50
21	1.	.05	.05	.22	1.25
22	0.	0.00	0.00	0.00	0.00
23	1.	.05	.05	.22	1.25
24	1.	.05	.05	.22	1.25

\*Due to space limitations, the data for only the first two days of the week are shown above.

**II. Statistics for Each Week Under Study**

WEEK	COUNT	AVERAGE	VARIANCE	STD. DEV.	PERCENT
1	1.	.01	.01	.11	1.25
2	4.	.05	.05	.21	5.00
3	3.	.04	.03	.19	3.75
4	3.	.04	.03	.19	3.75
5	1.	.01	.01	.11	1.25
6	6.	.07	.07	.26	7.50
7	3.	.04	.05	.19	3.75
8	2.	.02	.02	.15	2.50
9	4.	.05	.05	.21	5.00
10	2.	.02	.02	.15	2.50
11	4.	.05	.05	.21	5.00
12	6.	.07	.07	.26	7.50
13	3.	.04	.03	.19	3.75
14	6.	.07	.07	.26	7.50
15	4.	.05	.05	.21	5.00
16	7.	.08	.08	.28	8.75
17	5.	.06	.06	.24	6.25
18	6.	.07	.07	.26	7.50
19	3.	.04	.03	.19	3.75
20	4.	.05	.05	.21	5.00
21	3.	.04	.03	.19	3.75

\*\*\*TOTAL DEMAND ANALYZED WAS 80. CALLS.





### Sample ZAP Problem

The ZAP sample problem is to calculate the average and total number of calls of four types—gunshot/violence, drug-related, accidental injury, and unconscious persons—from each serial zone in the city of Austin. The problem parameters are depicted in Table 2.9.

Table 2.9 ZAP Sample Problem	
Variable	Sample Values
Type call*	gun, drug, accident, unconscious
Zones	all zones
Time period	all months
Ambulance	all ambulances
Transport/no-transport	all calls
Dispatch zones	any zones

\*Indicates that a set of parameter cards would be required in the program deck.

The actual card deck would include the computer control cards, the block A AGGREGATE card, block F cards, and the GOMAN card (see Figure 2.2). All but block F parameter values are the same as the initial default values. Thus, only block F cards need to be punched; these will be identical to the cards used in the sample CAP problem.

ZAP generates four output tables: (a) a list of error messages; (b) a summary of the user's parameter requests; (c) a table of the total number of calls in each serial zone for the ZAP analysis; and (d) a table of the average daily calls in each serial zone for the ZAP analysis. The error messages and user parameter summaries are identical to those produced by CAP. Tables 2.10 and 2.11 illustrate the summary statistics that are generated by ZAP for the sample problem.

Table 2.10 lists the total number of calls in each zone for the four incident types. The ten columns list the zones of the city in groups of ten; that is, the first row corresponds to zones 1 through 10, the second row to zones 11 through 20, and so forth. The 0 through 350 column along the left margin simply lists the number of the last zone on the previous row. For example, there were 5 calls of the type analyzed in Zone 187. There were 147 days analyzed. Thus the 5 calls represent 0.034 calls per day as shown in Table 2.11.

Table 2.11, which is read from left to right, shows the average number of daily calls from each of the 358 city

Figure 2.2  
Complete Deck for the ZAP Sample Problem

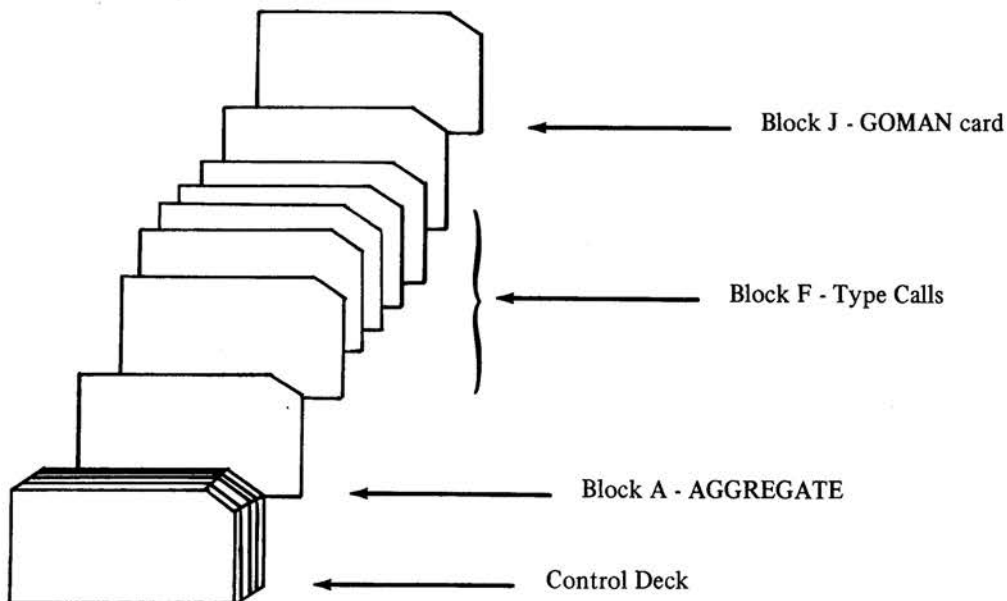


Table 2.10  
Total Calls in Each Zone for Sample Problem

SUMMARY OF ZONE COUNTS										
	1	2	3	4	5	6	7	8	9	10
0	0	6	2	1	3	3	3	6	3	1
10	1	0	3	8	0	8	1	0	6	1
20	2	1	8	8	4	1	5	4	1	0
30	0	1	2	2	0	0	2	0	1	0
40	4	2	0	5	3	2	7	4	0	2
50	5	1	5	2	1	8	5	2	5	4
60	4	5	4	3	3	8	15	0	3	2
70	1	0	1	2	2	9	1	1	6	1
80	2	3	1	1	1	2	1	7	7	3
90	3	1	3	7	0	5	9	2	0	11
100	3	2	3	1	1	8	7	1	2	10
110	2	5	4	16	15	15	5	17	6	0
120	1	2	6	0	0	2	5	2	8	0
130	8	1	2	0	2	2	1	3	0	3
140	5	8	1	3	7	0	11	5	3	2
150	0	7	3	1	11	4	1	0	0	1
160	0	9	8	13	8	3	4	11	20	7
170	4	6	11	21	5	1	5	15	2	21
180	3	10	14	4	4	10	5	3	7	5
190	6	3	6	1	6	1	0	0	4	1
200	4	3	2	3	2	2	1	5	0	5
210	0	5	2	11	5	3	5	0	0	3
220	5	1	3	1	0	2	0	0	0	2
230	6	5	1	2	4	6	10	9	1	1
240	5	3	14	3	0	0	0	1	2	0
250	6	1	6	5	5	6	2	7	0	1
260	7	0	6	2	10	1	3	0	7	2
270	0	0	2	1	1	0	0	0	0	0
280	4	4	0	0	0	2	1	0	0	0
290	0	0	0	0	0	1	0	0	0	2
300	2	0	0	0	0	0	1	0	4	2
310	2	0	5	1	6	0	0	0	0	0
320	0	0	0	6	0	0	4	0	2	0
330	0	0	0	1	3	0	0	0	0	0
340	2	0	0	0	0	0	2	1	0	0
350	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF DATA POINTS ANALYZED = 1100  
 AVERAGE PER ZONE = 3.7899  
 VARIANCE ABOUT AVERAGE = 14.07  
 STANDARD DEVIATION = 3.7504

TOTAL NUMBER OF RECORDS READ = 4332

**Table 2.11**  
**Average Number of Daily Calls per Zone**

ZONAL DAILY AVERAGES										
	1	2	3	4	5	6	7	8	9	10
0	0.000	.041	.014	.007	.020	.020	.020	.041	.020	.027
10	.007	0.000	.020	.054	0.000	.054	.007	0.000	.041	.007
20	.014	.007	.054	.054	.027	.007	.034	.027	.007	0.000
30	0.000	.007	.014	.014	0.000	0.000	.014	0.000	.007	0.000
40	.027	.014	0.000	.034	.020	.014	.048	.027	0.000	.014
50	.034	.007	.034	.014	.007	.054	.034	.014	.034	.027
60	.027	.034	.027	.020	.020	.054	.102	0.000	.020	.014
70	.007	0.000	.007	.014	.014	.061	.007	.007	.041	.027
80	.014	.020	.007	.007	.007	.014	.007	.048	.048	.020
90	.020	.007	.020	.048	0.000	.034	.061	.014	0.000	.075
100	.020	.014	.020	.007	.007	.054	.048	.007	.014	.068
110	.014	.034	.027	.109	.102	.102	.034	.116	.041	0.000
120	.007	.014	.041	0.000	0.000	.014	.034	.014	.054	0.000
130	.054	.007	.014	0.000	.014	.014	.007	.020	0.000	.020
140	.034	.054	.007	.020	.048	0.000	.075	.034	.020	.014
150	0.000	.048	.020	.007	.075	.027	.007	0.000	0.000	.007
160	0.000	.061	.054	.088	.054	.020	.027	.075	.136	.048
170	.027	.041	.075	.143	.034	.007	.034	.102	.014	.143
180	.020	.068	.095	.027	.027	.068	<b>.034</b>	.020	.048	.034
190	.041	.020	.041	.007	.041	.007	0.000	0.000	.027	.007
200	.027	.020	.014	.020	.014	.014	.007	.034	0.000	.034
210	0.000	.034	.014	.075	.034	.020	.034	0.000	0.000	.020
220	.034	.007	.020	.037	0.000	.014	0.000	0.000	0.000	.014
230	.041	.034	.007	.014	.027	.041	.068	.061	.007	.007
240	.034	.020	.095	.020	0.000	0.000	0.000	.007	.014	0.000
250	.041	.007	.041	.034	.034	.041	.014	.048	0.000	.007
260	.048	0.000	.041	.014	.068	.007	.020	0.000	.048	.014
270	0.000	0.000	.014	.007	.007	0.000	0.000	0.000	0.000	0.000
280	.027	.027	0.000	0.000	0.000	.014	.007	0.000	0.000	0.000
290	0.000	0.000	0.000	0.000	0.000	.007	0.000	0.000	0.000	.014
300	.014	0.000	0.000	0.000	0.000	0.000	.007	0.000	.027	.014
310	.014	0.000	.034	.007	.041	0.000	0.000	0.000	0.000	0.000
320	0.000	0.000	0.000	.041	0.000	0.000	.027	0.000	.014	0.000
330	0.000	0.000	0.000	.007	0.000	0.000	0.000	0.000	0.000	0.000
340	.014	0.000	0.000	0.000	0.000	0.000	.014	.007	0.000	0.000
350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

\*\*\*MAIN\*\*\* PROGRAM ENDING...GOODBY AND THANKS FOR USING CHAP

serial zones. The table is read in a manner similar to Table 2.10. To find the average number of daily calls for the four call types for serial zone number 187, the user would read down the left marginal column to row 180 and then read across to column 7. This is the datum for zone number 187, and the average number of daily calls is 0.034 of the types analyzed.

#### ZAP Output in Punched Form

When executed at The University of Texas, ZAP can also generate output in the form of punched cards. Such card decks can be used as input to mapping or location analysis programs. Certain control cards must be changed—the GOMAN card should include the word "PUNCH" and an

"INDEX" card should be added to the parameter deck immediately following the GOMAN card. Tables 2.16 and 2.18 list the required format changes for punched ZAP output.

Table 2.12 depicts the information found on ZAP punched output cards. ZAP generates two computer card decks listing the daily average and total calls for each serial zone. Each deck is preceded by a title card with either "ZONAL TOTAL COUNTS" or "ZONAL DAILY AVERAGES" beginning in column five. A four-digit number in columns 31-34 identifies the data in the deck. The twenty columns of the card from column 41 through 60 contain

any title provided by the ZAP INDEX card of the input parameter deck (see Table 2.18).

The data cards corresponding to the zones will be in numerical order by zone. The data for each serial zone are punched with either an "A" for "ZONAL DAILY AVERAGES" or a "T" for "ZONAL TOTAL COUNTS." The data type, index number, and serial zone number are listed in columns 73, 74-77, and 78-80 respectively. A message giving the ID number of the deck and the title is included in the printed output to confirm punching of the deck.

**Table 2.12**  
**Information on ZAP Punched Output Cards\***

<i>Variable</i>	<i>Column(s)</i>	<i>Definition</i>	<i>Remarks</i>
<i>Single Title Card</i>			
ZONAL DAILY AVERAGES or ZONAL DAILY COUNTS	5-20 5-18	data deck that follows is for zonal daily averages data deck that follows is for zonal total counts	one of these will appear on the title card
identification number	31-34	describes data in deck	obtained from the ZAP parameter input deck (Table 2.18) [Block L, columns 11-14]
title	41-60	describes data in deck	obtained from the ZAP parameter input deck (Table 2.18) [Block L, columns 21-40]
<i>Each Punched Data Card</i>			
data	11-18	decimal value for number of calls for serial zone represented	
A or T	73 73	designates card as part of zonal daily averages deck designates card as part of zonal total counts deck	
identification number	74-77	identifies output deck	obtained from the ZAP parameter input deck (Table 2.18) [Block L, Columns 11-14]
zone index number	78-80	identifies city serial zone represented on this card (from 001 to 358)	

\*Punched output would include 718 cards—one deck each for daily averages and total calls. Each deck consists of one title card and 358 ordered serial zone data cards.

### THE RESPONSE ANALYSIS PROGRAM (RAP)

RAP provides the user with the relative and cumulative frequencies of four EMS system performance variables—response time, on-scene time, transport time, and time at the hospital. To execute RAP, the user inserts one block A card behind the CHAP control card with the word “FREQUENCY” punched out in the first columns. No other parameter blocks are necessary. No sample problem is provided, as RAP analyzes all available data; the selection of different parameters as in CAP or ZAP is not possible.

Table 2.13 lists RAP-generated information on EMS system performance for the city of Austin. The left-most column, titled “INTERVAL,” lists minutes from one through sixty. The first column under each of the four service parameters (titled DIST) shows the number of times

that an EMS vehicle performed the action between X-1 and X minutes, where X is the interval number (e.g., between 3 and 4 minutes if the interval is 4). The second column (titled FREQ) states the corresponding relative frequency of responses. The figure under the cumulative frequency column (CUM) indicates the total percentage of calls that were recorded between zero and X minutes.

For example, the third row under the response time service parameter indicates that the response time for 896 calls, or 20.7 percent of the total calls, was recorded as three minutes. The figure under the cumulative frequency column (0.379) means that in 37.9 percent of all cases, an EMS vehicle arrived on the scene in three minutes or less. A system average, variance, and standard deviation are provided at the bottom of the table for each of the service parameters.

### REFERENCES

- (1) Lyndon B. Johnson School of Public Affairs, *Location Techniques for Emergency Medical Service Vehicles: Volume III: Emergency Medical Service Calls in Austin—Description and Assumptions*, Policy Research

Project Report No. 34 (Austin: LBJ School of Public Affairs, The University of Texas at Austin, 1979).

- (2) Ibid., *Volume II: Travel Time Data—Description and Assumptions*.



Table 2.13  
RAP Frequency Tables

INTERVAL	RESPONSE TIME			TIME AT SCENE			TRANSPORT TIME			TIME AT HOSPITAL		
	DIST	FREQ	CUM.	DIST	FREQ	CUM.	DIST	FREQ	CUM.	DIST	FREQ	CUM.
1	228	.053	.053	179	.041	.041	20	.007	.007	7	.012	.012
2	517	.119	.172	96	.022	.064	92	.031	.037	6	.012	.024
3	896	.207	.379	67	.015	.079	176	.059	.096	18	.016	.040
4	929	.215	.593	93	.021	.100	232	.077	.174	21	.017	.057
5	712	.164	.758	141	.033	.133	252	.084	.258	26	.019	.076
6	453	.105	.862	163	.038	.171	272	.091	.348	34	.022	.098
7	263	.061	.923	247	.057	.228	257	.086	.434	43	.025	.123
8	148	.034	.957	275	.064	.291	256	.085	.520	55	.028	.151
9	98	.021	.978	381	.078	.361	267	.089	.609	82	.027	.178
10	39	.009	.987	204	.066	.426	232	.077	.686	76	.025	.204
11	15	.003	.991	383	.079	.496	188	.063	.749	79	.026	.230
12	13	.003	.994	295	.068	.564	167	.056	.804	115	.038	.268
13	18	.002	.996	258	.060	.624	159	.046	.851	155	.035	.303
14	5	.001	.997	228	.053	.677	117	.039	.890	106	.035	.338
15	3	.001	.998	217	.050	.727	86	.029	.919	118	.039	.377
16	3	.001	.998	174	.046	.767	51	.017	.936	108	.036	.413
17	0	0.000	.998	136	.031	.798	43	.014	.950	141	.047	.460
18	3	.001	.999	119	.027	.826	40	.013	.963	137	.046	.506
19	1	.000	.999	111	.026	.852	27	.009	.972	143	.048	.554
20	1	.000	1.000	85	.020	.871	16	.005	.978	129	.043	.597
21	0	0.000	1.000	78	.018	.889	8	.003	.980	113	.038	.635
22	0	0.000	1.000	60	.014	.903	8	.003	.983	125	.042	.677
23	0	0.000	1.000	58	.013	.916	11	.004	.987	151	.044	.721
24	0	0.000	1.000	54	.012	.929	6	.002	.989	111	.037	.758
25	0	0.000	1.000	52	.012	.941	7	.002	.991	93	.030	.788
26	0	0.000	1.000	45	.010	.951	2	.001	.992	121	.034	.822
27	0	0.000	1.000	32	.007	.959	4	.001	.993	78	.026	.848
28	0	0.000	1.000	31	.007	.966	2	.001	.994	82	.027	.875
29	0	0.000	1.000	24	.006	.971	2	.001	.994	59	.020	.895
30	0	0.000	1.000	14	.003	.975	1	.000	.995	61	.020	.915
31	0	0.000	1.000	15	.003	.978	2	.001	.995	53	.018	.933
32	0	0.000	1.000	10	.002	.980	2	.001	.996	42	.014	.947
33	0	0.000	1.000	12	.003	.983	8	0.000	.996	43	.014	.961
34	0	0.000	1.000	9	.002	.985	2	0.000	.996	44	.015	.976
35	0	0.000	1.000	4	.001	.986	1	.000	.996	44	.015	.991
36	0	0.000	1.000	2	.000	.987	0	0.000	.996	33	.010	.991
37	0	0.000	1.000	6	.001	.988	2	.001	.997	31	.010	.991
38	0	0.000	1.000	18	.002	.990	0	0.000	.997	25	.008	.999
39	0	0.000	1.000	3	.001	.991	0	0.000	.997	28	.009	.998
40	0	0.000	1.000	7	.002	.993	3	.001	.998	14	.005	.993
41	1	.002	1.000	2	.000	.993	1	.000	.998	17	.006	.999
42	1	.000	1.000	3	.001	.994	0	0.000	.998	19	.006	.995
43	0	0.000	1.000	5	.001	.995	2	.001	.999	12	.004	.999
44	0	0.000	1.000	1	.000	.995	1	.000	.999	17	.006	.995
45	0	0.000	1.000	6	.001	.997	0	0.000	.999	8	.003	.997
46	0	0.000	1.000	2	.000	.997	0	0.000	.999	5	.002	.999
47	0	0.000	1.000	1	.000	.997	0	0.000	.999	5	.002	.991
48	0	0.000	1.000	2	.000	.998	1	.000	1.000	4	.001	.992
49	0	0.000	1.000	2	.000	.998	0	0.000	1.000	6	.002	.994
50	0	0.000	1.000	0	0.000	.998	0	0.000	1.000	11	.004	.998
51	0	0.000	1.000	2	.000	.999	1	.000	1.000	8	.003	.999
52	0	0.000	1.000	0	0.000	.999	0	0.000	1.000	6	.002	.999
53	0	0.000	1.000	1	.000	.999	0	0.000	1.000	7	.002	.995
54	0	0.000	1.000	3	0.000	.999	0	0.000	1.000	1	.000	.995
55	0	0.000	1.000	1	.000	.999	0	0.000	1.000	0	0.000	.995
56	0	0.000	1.000	1	.000	.999	0	0.000	1.000	3	.001	.996
57	0	0.000	1.000	2	0.000	.999	0	0.000	1.000	9	.003	.999
58	0	0.000	1.000	0	0.000	.999	0	0.000	1.000	2	.001	1.000
59	0	0.000	1.000	3	.001	1.000	0	0.000	1.000	1	.000	1.000
60	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
61	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
62	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
63	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
64	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
65	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
66	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
67	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
68	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
69	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
70	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
71	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
72	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
73	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
74	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
75	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
76	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
77	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
78	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
79	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
80	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
81	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
82	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
83	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
84	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
85	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
86	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
87	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
88	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
89	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
90	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
91	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
92	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
93	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
94	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
95	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
96	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
97	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
98	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
99	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
100	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
101	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
102	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
103	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
104	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
105	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
106	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
107	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
108	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000	0	0.000	1.000
109	0	0.000	1.000	0								



## APPENDIX

This appendix contains information for keypunching computer cards for the three CHAP subprograms described in the users manual. Tables 2.14 and 2.15 are lists of the job control cards required to implement the CHAP program on the City of Austin and The University of Texas at Austin computer systems, respectively.

Table 2.16 lists control cards required if the user wishes

a ZAP-punched output from The University of Texas at Austin computer system. Table 2.17 is a listing of the cards needed to implement the CAP subprogram. Table 2.18 lists electives for the ZAP subprogram. Tables 2.19 and 2.20 list the computer cards used to run the example CAP and ZAP problems, respectively.

**Table 2.14**  
**CHAP Control Cards for the City of Austin Computer System**

Card Number	Keypunch Sequence on Card <sup>†</sup>								
	1	5	1	2	3	4	5	6	7
			0	0	0	0	0	0	0
1	//EM0763JT JOB ,STOVER,CLASS=2,TIME=5								
2	//JOB LIB DD DSN=USER1.LINKLIB,DISP=SHR								
3	// DD DSN=CITY1.LINKLIB,DISP=SHR								
4	//ST1 EXEC PGM=EM1001F								
5	//FT02F001 DD DSN=EM,CALLDATA,UNIT=TAPE,DISP=(OLD,KEEP),								
6	// LABEL=(,SI),DCB=(LRECL=80,BLKSIZE=19040,RECFM=FB),VOL=SER=000161								
7	//FT06F001 DD SYSOUT=A								
8	//FT01F001 DD DUMMY								
9	//FT05F001 DD *								
	[parameter blocks A through K]								
10	/*								
11	//SYSOUT DD SYSOUT=A								
12	//								

<sup>†</sup>The text on each control card should be typed in the columns shown. The use of brackets and lower case letters indicates that a deck of computer cards follows.

**Table 2.15**  
**CHAP Control Cards for The**  
**University of Texas Computer System\***

<i>Card Number</i>	<i>Contents</i>
1	(user number)
2	(password)
3	JOB,TM=50,PR=100
4	COPYBR INPUT DATA
5	READPF 3472 EMSCALL
6	REWIND DATA
7	REWIND EMSCALL
8	EXEC PF 3473 XCHAP4,DATA, EMSCALL
9	(7/8/9 multipunch)  [parameter blocks A through K]
10	(6/7/8/9 multipunch)

\*The text on each control card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the punch instructions. Brackets refer to a deck of computer cards.

**Table 2.16**  
**CHAP Control Cards for The University of Texas Computer**  
**System for ZAP Punched Output\***

<i>Card Number</i>	<i>Contents</i>
1	(user number)
2	(password)
3	JOB,TM=50,PR=100,PU=400
4	COPYBR INPUT DATA
5	READPF 3472 EMSCALL
6	REWIND DATA
7	REWIND EMSCALL
8	EXEC PF 3473 XCHAP4,DATA,EMSCALL , , , PUNCH
9	(7/8/9 multipunch) [parameter blocks A through K]
10	(6/7/8/9 multipunch)

\*The text on each control card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the punch instructions. Brackets refer to a deck of computer cards.

\*\*See Table 2.18 and the text section on ZAP for further details.

**Table 2.17**  
**Electives for CAP Parameter Deck**

<i>Parameter Block</i>	<i>Card Number</i>	<i>Definition</i>	<i>Column(s)</i>	<i>Variable</i>	<i>Value*</i>	<i>Default Option</i>	<i>Remarks</i>
A	1	selects CAP option	1-7	ANALYZE	A		
B	1	specifies area of interest	1-4	ZONE	A	all zones	
		all areas	11-13	ALL	A		
		ranges of zones	11-15	RANGE	A		
		individual zones	11-16	NUMBER	A		
	2 to (n-1)	if RANGE on card 1	21-24 25-28	lowest zone number of range highest zone number of range	I I		the symbols "2 to (n-1)" indicate that there may be more than one card; maximum number of cards indicated in these remarks; no more than five RANGE cards.
	2 to (n-1)	if NUMBER on card 1	21-24	zone number	I		maximum of ten zones per card; maximum of five ZONE cards; thus no more than 50 zones
			25-28	zone number	I		
			.	.	.		
			.	.	.		
			57-60	zone number	I		
	n**	completes parameter block of cards	1-3	END	A		necessary only if RANGE or NUMBER on first card in B
C	1	specifies period of interest for days for weeks	1-6	PERIOD	A	week option	
			11-14	DAYS	A		
			11-14	WEEK	A		
	2 to (n-1)	specification of days	1-4	MOND	A		can use any combination of days; one to a card; maximum of seven DAYS cards.
				TUES	A		
				WEDN	A		
				THUR	A		
				FRI	A		
	X	follows last DAYS card		SATU	A		not required for WEEK option
				SUND	A		
				END	A		
D	1	specifies an interval of time	1-8	INTERVAL	A	six-hour interval	
	2	numeral for the hour interval	1-3	1 or	I		one interval per run; any interger factor of 24 possible
				2 or	I		
				.	.		
				.	.		
E	2	indicates the limits of the period	1-2	24	I		
				number of beginning month (January = 1)	I		
				beginning data	I		
				number of ending month	I		
	1	specifies that a period of the data set will be analyzed	1-4	TIME	A	entire data set	
F	2	indicates the limits of the period	1-2	ending data	I		
				3-4	I		
				5-6	I		
				7-8	I		
	1	specifies type of emergency call to be analyzed	1-4	TYPE	A	all types	
		if all types to be analyzed	11-13	ALL	A		
			11-14	SOME	A		

\* I = integer, punched right justified in the field  
A = alphabetical characters punched in the field beginning in the first column

\*\* n = indicates final card in the parameter block



Table 2.17 (continued)

Parameter Block	Card Number	Definition	Column(s)	Variable	Value*	Default Option	Remarks
	2 to (n-1)	if SOME appears on first F card	1-4	AUTO DRUG GUN ACCIDENT HEART SEIZURE STROKES BABY HOUSE UNCON UNKNOWN	A A A A A A A A A A		no more than eleven cards; one type to a card
	n	completes parameter block of cards	1-3	END	A		
G	1	identifies the ambulances under study	1-9	AMBULANCE	A	all ambulances	
		if all vehicles under study	11-13	ALL	A		
		if one or more vehicles under study	11-14	SOME	A		
	2	if SOME appears on first G card	21-24 25-28 . . . . 57-60	index number of a vehicle	I I . . . . I		this card identifies vehicles; maximum of ten ambulances
H	1	identifies zones from which ambulances are dispatched	1-8	DISPATCH	A	any zones allowed	
		if any zones allowed	11-13	ALL	A		
		if only certain zones	11-14	SOME	A		
	2	if SOME appears on first H card	21-24 25-28 . . . . 57-60	number identifying dispatch zone	I I . . . . I		this card identifies base zone; maximum of ten zones
I	1	identifies whether user wants to analyze transport calls or not	1-9	TRANSPORT	A	all calls	
		if all calls are to be analyzed	11-13	ALL	A		
		if only transport calls are to be analyzed	11-19	TRANSPORT	A		
		if only non-transport calls are to be analyzed	11-17	NOTRANS	A		
J	1	initiates CAP program	1-5	GOMAN	A	NOPRINT is the default	
		if matrix or frequencies of calls is required	11-15	PRINT	A		
		if matrix of frequencies is not required	11-17	NOPRINT			
K	1	allows user to execute multiple analyses on single CAP run					
		run analysis with minor modifications (use current default values)	1-8	CONTINUE	A		indicates continued use of current variable values, but allowing for changes.
		run analysis with initial default values and possibly some new block values	1-8	RESTART	A		indicates restart, using initial default values, but permitting change

Note: This table does not include all CAP options. Refer to text for additional information.

**Table 2.18**  
**Electives for ZAP Parameter Deck\***

<i>Parameter Deck</i>	<i>Card Number</i>	<i>Variable</i>	<i>Role</i>	<i>Columns</i>	<i>Remarks</i>
A	1	AGGREGATE	selects ZAP option	1-9	
B through I	decks	—	program parameter cards		blocks C, E, F, G, H, and I are used in the same way as in the CAP program; refer to Table 17  blocks B and D are not used in the ZAP program
J	1	GOMAN PUNCH	initiates ZAP program includes punched cards in output	1-5 11-15	use only for generating punched output
L	1	INDEX	title option for punched card output	1-5	use only for generating punched output
		identification	provides identification number	11-14	integer value punched right justified in field
		title	provides title for output cards	21-40	

\*Alphabetical variables begin in first column indicated. Numerical values are right justified.

Table 2.19

## CAP Sample Problem Deck

Card Number	1	5	10	15	20	25	30
1	(user number)						
2	(password)						
3	JOB, TM=50, PR=100						
4	COPYBR INPUT DATA						
5	READPF 3472 EMSCALL						
6	REWIND DATA						
7	REWIND EMSCALL						
8	EXEC PF D600 XCHAP4, DATA, EMSCALL						
9	(7/8/9 multipunch)						
10	ANALYZE						
11	ZONE $\xleftrightarrow{6}$ RANGE						
12	$\xleftrightarrow{20}$						00010022
13	$\xleftrightarrow{20}$						00510055
14	$\xleftrightarrow{20}$						01660167
15	END						
16	TYPE $\xleftrightarrow{6}$ SOME						
17	GUN						
18	DRUG						
19	ACCIDENT						
20	UNCON						
21	END						
22	INTERVAL						
23	002						
24	GOMAN						
25	(6/7/8/9 multipunch)						

**Table 2.20**  
**ZAP Sample Problem Deck**

<i>Card Number</i>	1	5	10	15	20	25
1	(user number)					
2	(password)					
3	JOB,TM=50,PR=100					
4	COPYBR INPUT DATA					
5	READPF 3472 EMSCALL					
6	REWIND DATA					
7	REWIND EMSCALL					
8	EXEC PF D600 XCHAP4,DATA,EMSCALL					
9	(7/8/9 multipunch)					
10	AGGREGATE					
11	TYPE ← <sup>6</sup> → SOME					
12	GUN					
13	DRUG					
14	ACCIDENT					
15	UNCON					
16	END					
17	GOMAN					
18	(6/7/8/9 multipunch)					

## Chapter 3

# A Manual for Users of the CALL/CZSR Program

This chapter describes CALL/CZSR, a computer program designed to identify and evaluate good sites for locating emergency medical vehicles. The first section describes the operations of the program, its assumptions, and the application of this program to the analysis of EMS vehicle sites for the city of Austin. The second section explains the information required to run the program and the statistics that the program generates. The final section reports the results of an illustrative Austin run and describes the use of CALL/CZSR in the development of vehicle deployment policies.

### DESCRIPTION OF THE CALL/CZSR MODEL

CALL/CZSR is the name of two computer routines that work together to evaluate potential EMS vehicle sites. CALL (Computerized Ambulance Location Logic) uses queuing theory to evaluate several parameters, including the expected vehicle travel time for the EMS system. CZSR (Computerized Zone Search Routine) tries to improve upon a set of trial sites by substituting neighboring zones in an attempt to reduce the mean response time. Subsequent repetitions of the CALL and the CZSR routines allow the program to find a set of trial sites that reduce the system mean travel time.

The CALL/CZSR program begins with a user-supplied set of trial vehicle sites. Using this given number and location of EMS vehicles, CALL calculates a system mean response time based on a  $M/G/\infty$  queuing model.\* The queuing model predicts the availability of EMS vehicles, given parameters representing (a) the arrival rate and geographic distribution of calls for service, (b) the average EMS service time, and (c) the number of EMS vehicles.

In a real EMS system, a vehicle's response time is dependent on the number and identity of the EMS vehicles busy when a call is received. Monte Carlo simulation methods are used to estimate the response times, conditional on  $m$  busy vehicles out of  $M$  vehicles deployed ( $m = 0, 1, \dots, M$ ). Then

---

\* The different waiting and service events in an emergency system suggest that EMS can be modeled as a queuing, or waiting line, system. The notation " $M/G/\infty$ " indicates that the call arrival process is Poisson, that the service times follow a general distribution with a finite mean and variance, and that there is an infinite number of vehicles (a vehicle will always be free to respond to a call for service).

the model (a) assumes a distribution of the number of busy vehicles; (b) estimates the mean, unconditional service time; (c) estimates the distribution of the number of busy vehicles from the  $M/G/\infty$  model; and (d) iterates between steps (b) and (c) until the model converges. More detailed explanations of the CALL/CZSR program are available in publications by Professor James Fitzsimmons (1).

Travel time is the major performance measure used by CALL/CZSR in evaluating a set of EMS vehicle locations. Locations supplied as input by the user may perform well with regard to this criterion, or they may not. The CZSR routine searches for a set of locations giving a smaller mean travel time.

Given the evaluation of system performance calculated by CALL, the CZSR routine proceeds to move vehicles one at a time to neighboring zones. Each move is checked by CALL to evaluate system performance for the trial location. For each vehicle site, a search is made of each of its contiguous zones for a possible improvement in average response time for all calls in the system. The best move for each vehicle and the combined effect of simultaneously moving each ambulance to its best trial location is recorded. If a move improves upon the previous set of locations, then that configuration becomes the new trial deployment. This new set of locations may thus represent a change in one or all vehicle sites.

CALL/CZSR terminates when the system mean response time cannot be improved significantly, or when the number of search evaluations exceed a user-specified limit. The analyst must remember that CALL/CZSR is a heuristic model, and that any "best" set of locations determined by the model represents what could be called a "limited local optimum." As the search routine is limited to evaluating only zones contiguous to a trial EMS vehicle site, there is no guarantee that the routine will find the systemwide optimum—the set of sites with the smallest mean response time to all calls. An analogy would be a mountain climber who seeks to find the highest point in a mountain range and does so by trying to go up by moving in any direction. If he checks all directions he will find a true local optimum. But if he checks only due north, south, east, and west and none of the 356 other degrees on the compass, he may not even get a true local optimum. CALL/CZSR checks only neighboring zones and checks single zone moves, rather than all pairs, triplets, or other possible multiple zone shifts, except for the shift corresponding to all vehicles moving to their best contiguous zones.

## CALL/CZSR PROGRAM INPUTS

To run the CALL/CZSR program, the user must supply the computer with four types of inputs:

- interzonal travel times;
- EMS demand data;
- EMS system parameters;
- initial EMS vehicle sites.

This section illustrates each of these input types by referring to data used in an evaluation of the six Austin EMS vehicle sites in use during January 1980.

The assumptions made in the CALL/CZSR location model are summarized in Table 3.1. The third column of this table describes the way in which these assumptions were applied to the analysis of the Austin EMS system.

The CALL/CZSR program requires information on the travel times between zones. The zones used in the Austin study are the 358 serial zones shown in Figure 3.1. Response times to each zone from any other zone have been approximated by a projection of interzonal travel times developed by the Austin Transportation Study Office. This matrix, based on travel projections in Austin for 1995, is a list of the travel time from each zone centroid to all other zone centroids (2). These projections assume that (a) present traffic demand trends will continue, and (b) that several planned future highways will be completed.

One surrogate for EMS call demand is the relative likelihood that a request for EMS service will occur in a zone, based on historical call data. The demand measure used in the Austin study is the relative frequency\* of emergency calls received in each serial zone during a five-month period in 1976 and 1977 (3). Both the relative demand frequency and the travel time matrix are stored on computer tapes. A partial reprint of the CALL/CZSR output in Table 3.2 shows the relative frequency of calls by zone as an array of real numbers that sum to 1.0. The relative demand for EMS service originating in zones 1 through 20 is listed in row 1, the relative demand for zones 21 through 40 is in row 2, and so on. For example, the relative demand for EMS service in zone 61 is 0.0023; it is the 61st number on the matrix, or the first number in the fourth row.

Table 3.2 also displays a list of parameters that describe various aspects of Austin's EMS system. These parameters and their values, which are directly above the demand matrix, are explained in Table 3.3.

The user must supply the system with an initial set of EMS vehicle sites and a set of emergency care hospital sites. In this Austin example problem, those zones corresponding to current EMS vehicle locations were chosen as the initial

\* Relative frequency for a zone is the number of calls originating from that zone divided by the total number of EMS calls.

vehicle sites. The hospital site is the serial zone containing Brackenridge Hospital. These items are listed in Table 3.2 below the demand data matrix. Precise formats for CALL/CZSR input data keypunching are contained in the appendix.

## CALL/CZSR PROGRAM OUTPUT

The CALL/CZSR program first prints out the user-supplied inputs and summarizes its work. Later pages contain information evaluating the performance of the EMS vehicle locations. This section discusses the performance statistics for individual vehicles and the EMS system, the response time data, and the first-in vehicle array.

Table 3.4 restates system parameters and the number of evaluations made in this run. In this example, CALL evaluated 266 possible site changes, well below the upper limit of 500. CALL/CZSR terminated when it could not find a set of vehicle locations that could reduce the system mean response time by more than 0.001 minutes.

Table 3.5 lists several measures of individual ambulance performance: MEAN RESPONSE, CALLS PER DAY, PERCENT OF CALLS, and PERCENT UTILIZED. These statistics are presented in two tables, one for the initial vehicle locations (trial sites), and the other for the final locations after the CZSR program moved them. Table 3.6 defines the statistics shown in Table 3.5.

Table 3.7 shows EMS system response times calculated for the various system states (i.e., the number of busy vehicles at the time that a call for service is received). Table 3.7 also lists the likelihood of occurrence of each system state and average system response times for both initial and final vehicle sites. For example, the probability that exactly one vehicle is busy is 0.3677 for the initial vehicle site configuration. Mean response time for the system is 5.271 minutes when one vehicle is busy. The definition of mean system response time when all vehicles are busy is the average travel time to any zone by a vehicle that is dispatched from an emergency care facility (in this example, Brackenridge Hospital).

Table 3.7 also lists several other measures of system performance under the heading "STATISTIC": MEAN RESPONSE, MEAN TIME TO HOSPITAL, MEAN RETRIEVAL TIME, MEAN SERVICE TIME, and MEAN NUMBER IN SYSTEM. These terms are defined in Table 3.8.

CALL/CZSR uses a 1000-call sample in a Monte Carlo simulation of response times. These estimates yield a relative and a cumulative frequency distribution of response for both initial and final vehicle site configurations (see Table 3.9).

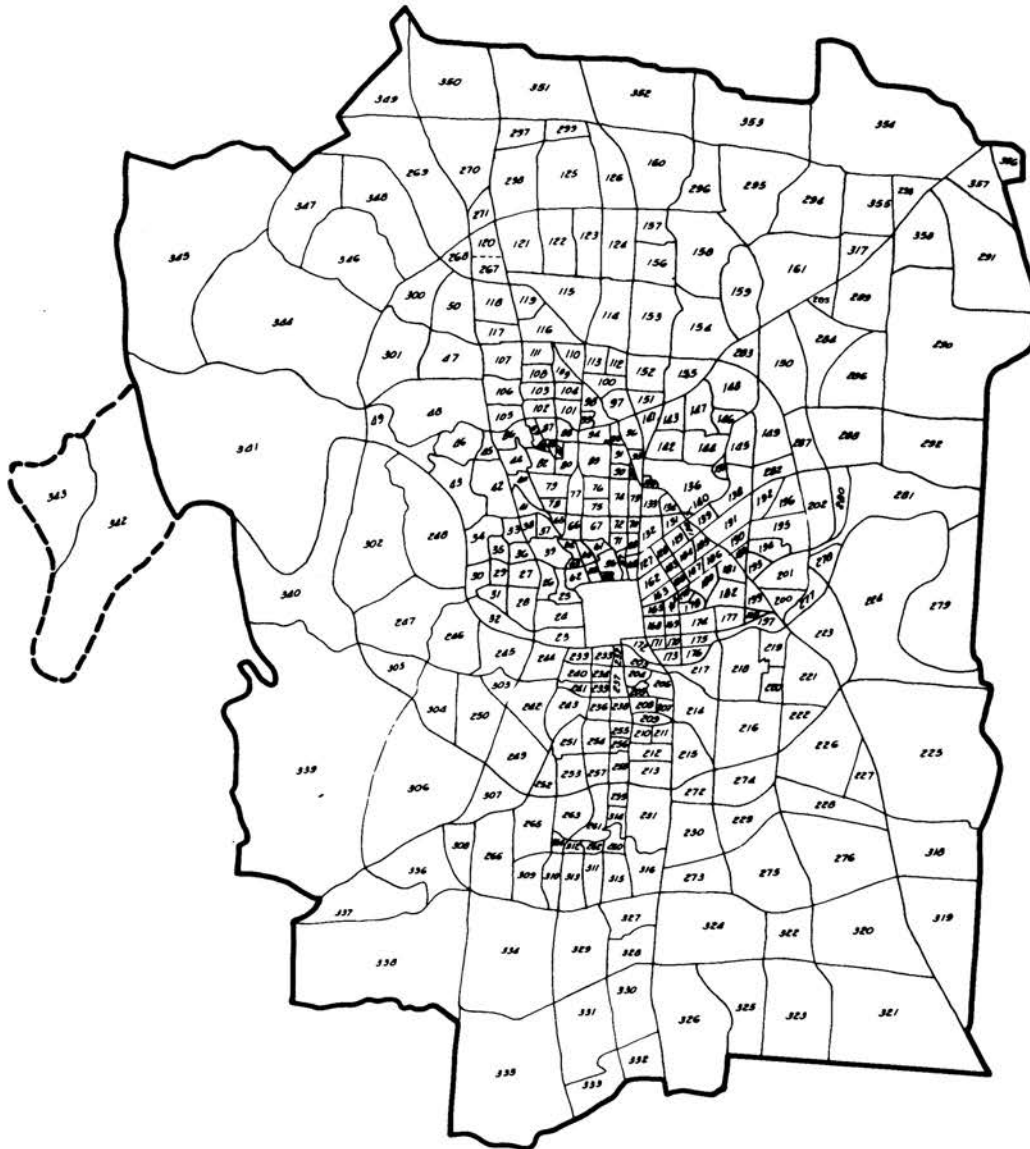
To illustrate the use of this table, assume the analyst wishes to know the likelihood of a vehicle reaching a call in



**Table 3.1**  
**Assumptions of the CALL/CZSR Model as Applied to Austin**

<i>Subject</i>	<i>Model Assumption</i>	<i>Austin Application</i>
City or area structure	A set of discrete districts represented by central points that are connected by travel time links	A set of 358 zones represented by centroids that are connected by travel time links
Potential vehicle sites	Any zone centroid	Any zone's centroid of population concentration
Origin of calls for EMS service	Any zone centroid	Any zone's centroid of population concentration
Demand for EMS service	Calls occur according to a Poisson process in each zone; the rate for each zone is determined by the historical call rate for the zone	The historical call rate from each zone based on call data collected by EMS dispatchers in December, 1976, and January, June, July, and August, 1977
Interzonal travel time	Travel times may be given as actual times or as interzonal distances	A study by the Austin Transportation Study Office provided travel times between any zone and each other zone
Vehicle characteristics	Vehicles are identical	Vehicles are identical in speed of response and in equipment
Personnel characteristics	The personnel at each location have equal expertise	The personnel at each location have equal expertise
Vehicle availability	There will always be an available vehicle that can respond to a call	There will always be an available vehicle that can respond to a call
Vehicle dispatch	The closest available vehicle is dispatched	The closest available vehicle is dispatched from its station
Program objective	The CALL/CZSR objective is to minimize average system response time	Minimize the average response time for the Austin EMS system
Other measurements of effectiveness	It is desirable to have an equal workload for each vehicle	It is desirable to reduce any differences between the maximum and minimum vehicle workloads
Termination of CALL/CZSR routine	Termination occurs at a user-specified search limit or when system mean response time cannot be improved significantly	Termination occurs at a user-specified search limit or when system mean response time cannot be improved by more than 0.001 minutes

**Figure 3.1**  
**Serial Zone Map of Austin, Texas**



NOTE: Map numerals indicate serial zone reference numbers

Table 3.2  
Input Data Used in CALL/CZSR Austin Run

ASSIGNMENT OF AMBULANCE LOCATIONS

LAMDA = 38.00 LIMIT= 500 CARE = 15.00 TRSFR = 20.00  
NAMB = 6 MHOSP = 1 NDIST = 358 NFRAC = 30 TRANS = .60

```
.0009 .0060 .0007 .0007 .0018 .0028 .0028 .0046 .0014 .0012 .00050 .0000 .0021 .0021 .0035 .0081 .0023 .0007 .0028 .0037
.0018 .0012 .0027 .0053 .0032 .0016 .0028 .0037 .0021 .00140 .0000 .0016 .0009 .00140 .0000 .0009 .0023 .0016 .0028 .0014
.0042 .0014 .0007 .0018 .0023 .0016 .0035 .0040 .0000 .0042 .0039 .0007 .0039 .0012 .0021 .0032 .0021 .0009 .0039 .0042
.0023 .0028 .0035 .0030 .0032 .0032 .0074 .0007 .0014 .0014 .0016 .0021 .0046 .0039 .0044 .0076 .0014 .0016 .0053 .0018
.0007 .0023 .0005 .0016 .0025 .0016 .0042 .0053 .0053 .0032 .0014 .0014 .0032 .0039 .0007 .0028 .0051 .0048 .0005 .0039
.0053 .0035 .0014 .0023 .0037 .0037 .0060 .0032 .0025 .0055 .0018 .0051 .0039 .0050 .0069 .0018 .0051 .0076 .0044 .0032
.0016 .0030 .0055 .0016 .0002 .0009 .0042 .0023 .0097 .0007 .0032 .0048 .0035 .0002 .0018 .0025 .0009 .0023 .0018 .0025
.0065 .0062 .0023 .0032 .0069 .0002 .0069 .0042 .0023 .0014 .0009 .0044 .0044 .0025 .0067 .0035 .00050 .0000 .0000 .0039
0.0000 .0090 .0090 .0005 .0074 .0025 .0058 .0010 .0011 .0039 .0032 .0062 .0072 .0069 .0042 .0044 .0028 .0002 .0039 .0009
.0023 .0018 .0001 .0062 .0048 .0005 .0025 .0035 .0058 .0042 .0076 .0046 .0018 .0007 .0072 .00180 .00000 .0000 .0035 .0016
.0032 .0021 .0048 .0028 .0021 .0025 .0025 .0055 .0023 .0032 .0005 .0032 .0037 .0022 .0069 .0033 .0063 .0027 .0023 .0005
.0065 .0030 .0016 .0014 .0007 .00140 .00000 .0000 .0007 .0009 .0044 .0032 .0016 .0039 .0039 .0074 .0055 .0025 .0025 .0032
.0044 .0030 .0005 .0012 .0002 .00020 .0000 .0009 .00250 .0000 .0062 .0018 .0074 .0053 .0039 .0039 .0021 .0065 .0012 .0021
.0042 .0007 .0079 .0012 .0079 .0002 .0030 .0002 .0012 .0012 .0002 .0005 .0032 .0012 .00070 .0009 .00120 .00000 .00000 .0033
.0016 .0021 .00020 .00000 .0000 .0009 .0016 .00070 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .0033
.00180 .00000 .00000 .00000 .0000 .0002 .00070 .0000 .0021 .0012 .0025 .0007 .0021 .0021 .0025 .00180 .00000 .00000 .00000 .0033
0.00000 .00000 .0000 .00460 .00000 .0000 .0014 .0005 .00350 .00000 .00000 .00000 .00000 .0012 .0002 .00320 .00000 .00330 .00000 .0033
.0016 .00020 .00000 .00000 .00000 .0000 .0016 .00120 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .0033
```

HOSPITAL LOC IN DIST #

BRACKINRIDGE 55

AMB	TYPE	LOC	IN	DIST
1	1	256		
2	1	256		
3	1	59		
4	1	180		
5	1	152		
6	1	118		

Table 3.3

## EMS System Variables Used in CALL/CZSR

Name	Definition
LAMBDA	The average number of calls per day
LIMIT	A limit on the number of contiguous zone substitutions to be evaluated prior to the program's termination
CARE	The average time required by EMS staff for on-scene care
TRSF	The average amount of time a vehicle spends at the hospital for patient transfer
NAMB	The number of EMS vehicles in the system
NHOSP	The number of emergency care facilities in the system
NDIST	The number of serial zones
NFRAC	The number of one-minute intervals for the response distribution tables provided in the program output
TRANS	The probability that a call for EMS service will result in a transfer of a patient from the scene of the accident to a hospital

Table 3.4

## System Parameters Listed in CALL/CZSR Printout

SYSTEM PARAMETERS	
MEAN ON SCENE CARE TIME (MIN)	15.00
MEAN TRANSFER TIME AT HOSPITAL (MIN)	20.00
PROBABILITY OF TRANSPORT	.60
MEAN NUMBER OF INCIDENTS PER DAY	30.00
NUMBER OF AMBULANCES	6
NUMBER OF HOSPITALS	1
NUMBER OF DISTRICTS	358
NUMBER OF SEARCH POINTS EVALUATED	266

Table 3.5

## Individual Ambulance Performance

## AMBULANCES

INITIAL LOCATION							FINAL LOCATION					
AMBULANCE	IN	DIST	MEAN RESPONSE	CALLS PER DAY	PERCENT OF CALLS	PERCENT UTILIZED	IN	DIST	MEAN RESPONSE	CALLS PER DAY	PERCENT OF CALLS	PERCENT UTILIZED
1		258	6.78	6.03	15.88	15.98		238	6.48	5.87	15.45	15.43
2		258	7.31	4.10	10.78	11.80		258	7.75	3.81	10.02	10.34
3		59	6.64	10.62	27.96	28.04		54	6.59	10.78	28.36	28.40
4		180	6.06	8.15	21.44	21.17		179	5.88	7.48	19.68	19.34
5		152	9.92	5.56	14.64	15.95		112	9.89	5.86	15.41	16.78
6		118	11.48	3.54	9.31	10.52		111	11.05	4.21	11.09	12.41

**Table 3.6**  
**CALL/CZSR Measures of Individual Ambulance Performance**

<i>Name</i>	<i>Definition</i>	<i>Comment</i>
Mean response	The average travel time from vehicle base to all first-in service areas	Assumes that a vehicle will always respond to calls where it is first-in and that it will respond to no other calls
Calls per day	The sum of all relative demand weights of all zones where a vehicle is first-in multiplied by 38, the average total calls per day	
Percent of Calls	The fraction of all calls from any zone multiplied by 100	100 converts the proportion to a percentage
Percent Utilized	Vehicle calls per day multiplied by mean vehicle service time multiplied by 100/1440	Estimate of the average percent of time a particular vehicle is busy based on first-in calls  100/1440 is a combined time-percentage conversion factor

**Table 3.7**  
**System Performance Statistics**

S Y S T E M   P E R F O R M A N C E				
NUMBER OF BUSY AMBULANCES	INITIAL LOCATION		FINAL LOCATION	
	PROBABILITY	MEAN RESPONSE (MIN)	PROBABILITY	MEAN RESPONSE (MIN)
0	.3795	4.838	.3837	4.489
1	.3677	5.271	.3675	4.808
2	.1782	5.770	.1760	5.385
3	.0575	6.960	.0562	6.245
4	.0139	8.660	.0135	8.350
5	.0027	11.610	.0026	10.693
6	.0005	7.276	.0005	7.276
STATISTIC		INITIAL	FINAL	
MEAN RESPONSE (MIN)		5.355	4.864	
MEAN TIME TO HOSPITAL (MIN)		47.631	47.208	
MEAN RETRIEVAL TIME (MIN)		7.276	7.276	
MEAN SERVICE TIME (MIN)		36.720	36.297	
MEAN NUMBER IN SYSTEM		.969	.958	

**Table 3.8**  
**CALL/CZSR Measures of System Performance**

<i>Statistic</i>	<i>Definition</i>
MEAN RESPONSE	The average response time for the system, taking into account the probability that the nearest vehicle(s) may be busy. The response time for each "system state" where more than one vehicle is busy is approximated through a Monte Carlo simulation.
MEAN TIME TO HOSPITAL	Average system response time plus average on-scene care time plus average travel time to the hospital plus average transfer time at the hospital.
MEAN RETRIEVAL TIME	The average travel time from any zone to the nearest hospital.
MEAN SERVICE TIME	Mean time to hospital weighted by the fraction of calls that require patient transport to a hospital, plus the sum of the mean response time and the mean on-scene care time, weighted by the fraction of calls that do not require patient transport to the hospital.
MEAN NUMBER IN SYSTEM	Estimates the average number of busy vehicles in the system.

**Table 3.9**  
**Distribution of CALL/CZSR Vehicle Responses**

CLASS INTERVAL	INITIAL	INITIAL	INITIAL	INITIAL
	PROBABILITY	CUMULATIVE	FINAL	CUMULATIVE
		PROBABILITY	PROBABILITY	PROBABILITY
0 - 1	0.0000	0.0000	0.0000	0.0000
1 - 2	.0260	.0260	.0336	.0336
2 - 3	.0352	.0612	.1190	.1495
3 - 4	.1410	.2021	.1446	.3342
4 - 5	.1998	.4020	.1838	.5179
5 - 6	.2036	.6056	.1473	.6652
6 - 7	.1425	.7481	.0936	.7588
7 - 8	.0878	.8359	.0889	.8477
8 - 9	.0743	.9102	.0566	.9043
9 - 10	.0392	.9494	.0456	.9499
10 - 11	.0170	.9664	.0241	.9740
11 - 12	.0130	.9794	.0053	.9793
12 - 13	.0073	.9867	.0056	.9850
13 - 14	.0034	.9901	.0031	.9881
14 - 15	.0022	.9923	.0057	.9938
15 - 16	.0033	.9956	.0012	.9950
16 - 17	.0007	.9963	.0021	.9971
17 - 18	.0004	.9967	.0005	.9976
18 - 19	.0016	.9983	.0001	.9977
19 - 20	.0005	.9988	.0003	.9979
20 - 21	.0001	.9989	.0013	.9993
21 - 22	.0000	.9989	.0000	.9993
22 - 23	.0001	.9990	.0001	.9993
23 - 24	.0003	.9993	.0000	.9993
24 - 25	.0000	.9993	.0000	.9994
25 - 26	.0000	.9993	.0000	.9994
26 - 27	.0002	.9995	.0000	.9994
27 - 28	.0000	.9995	.0000	.9994
28 - 29	.0000	.9995	.0002	.9995
29 - 30	.0000	.9995	.0000	.9995
MAXIMUM RESPONSE TIME		36.0000	36.0000	



**Table 3.10**

### Portion of the First-In Ambulance Array for the Austin CALL/CZSR Run

FIRST-IN AMBULANCE ARRAY

DIST. NO.      AMBULANCE NUMBER (FIRST-IN LEFT TO RIGHT)

1	3	4	1	2	5	6
2	3	4	1	2	5	6
3	3	4	1	2	5	6
4	3	4	1	2	5	6
5	3	4	1	2	5	6
6	3	4	1	2	5	6
7	3	4	1	2	5	6
8	3	4	1	2	5	6
9	3	4	1	2	5	6
10	3	4	1	2	5	6
11	3	1	4	2	5	6
12	3	4	1	2	5	6
13	3	4	1	2	5	6
14	3	4	1	2	5	6
15	3	4	1	2	5	6
16	3	1	4	2	5	6
17	3	1	4	2	5	6
18	3	1	4	2	5	6
19	3	4	1	2	5	6
20	3	1	4	2	5	6
21	3	1	4	2	5	6
22	3	1	4	2	5	6
23	3	1	4	2	6	5
24	3	1	4	2	5	6
25	3	4	1	2	6	5
26	3	4	1	2	5	6
27	3	1	4	6	5	2
28	3	1	4	2	6	5
29	3	4	1	6	5	2
30	3	1	4	6	2	5
31	3	1	4	2	6	5
32	3	1	4	2	6	5
33	3	6	5	4	1	2
34	3	6	4	1	5	2
35	3	1	4	6	5	2
36	3	1	6	4	5	2
37	3	6	5	4	1	2
38	3	6	5	1	4	2
39	3	1	4	5	6	2
40	3	5	6	4	1	2
41	3	6	5	4	1	2
42	6	3	5	1	4	2
43	6	3	5	4	1	2
44	6	5	3	4	1	2
45	6	3	5	1	4	2
46	6	5	3	4	1	2
47	6	5	3	1	4	2
48	6	5	3	1	4	2
49	6	5	3	4	1	2

less than five minutes. Reading across from the 4-5 minute class interval, a vehicle at the trial site configuration could travel to a call in less than five minutes 40 percent of the time.

Table 3.10 shows the first-in ambulance array, the ordered list of the closest EMS vehicle bases for each serial zone. For example, the first and second closest vehicle bases to serial zone 6 are the sites corresponding to vehicles 3 (zone 54) and 4 (zone 179), respectively (see Table 3.10).

Table 3.11 lists the travel times from each of the vehicle bases to each serial zone. The top line lists the current trial vehicle bases. Vehicles 3 and 4 are based in serial zones 54 and 179, respectively. Vehicles 3 and 4 are 2 minutes distant from serial zone 6 (see Table 3.11).

Table 3.12 lists the minimum response and mean response to any zone for the final site configuration. Minimum response is the time it takes for the first-in vehicle to reach a given zone. Mean response for each zone is the sum-

Table 3.11

**Portion of Travel Time Matrix  
for the Austin CALL/CZSR Run**

CURRENT AMBULANCES LOCATIONS	238	258	54	179	112	111
------------------------------	-----	-----	----	-----	-----	-----

6.	8.	2.	4.	9.	12.
6.	8.	2.	4.	9.	12.
6.	8.	2.	5.	10.	11.
5.	7.	2.	4.	10.	12.
5.	7.	2.	4.	10.	12.
5.	7.	2.	4.	9.	12.
5.	7.	2.	4.	9.	13.
5.	7.	2.	4.	10.	13.
5.	7.	3.	4.	10.	12.
5.	7.	3.	5.	10.	12.
5.	6.	3.	5.	11.	13.
5.	6.	3.	5.	10.	13.
5.	7.	3.	4.	10.	13.
5.	7.	2.	4.	10.	13.
5.	7.	3.	4.	10.	13.
4.	6.	3.	4.	10.	14.
4.	6.	3.	5.	11.	13.
4.	6.	4.	5.	11.	13.
5.	7.	3.	5.	10.	12.
5.	7.	4.	5.	11.	13.
6.	8.	4.	6.	11.	12.
5.	7.	4.	6.	12.	13.
7.	9.	6.	8.	13.	12.
7.	9.	4.	7.	12.	12.
8.	10.	5.	7.	12.	11.
9.	10.	5.	8.	11.	11.
9.	11.	6.	9.	11.	10.
8.	10.	6.	9.	12.	11.
10.	12.	7.	9.	12.	11.
10.	12.	7.	10.	13.	12.
9.	11.	7.	9.	13.	12.
8.	10.	7.	9.	13.	12.
11.	13.	8.	11.	10.	9.
12.	14.	9.	11.	12.	11.
10.	12.	7.	10.	12.	11.
10.	12.	7.	10.	11.	10.
10.	12.	6.	9.	9.	9.
10.	12.	7.	10.	9.	8.
9.	11.	6.	9.	10.	10.
12.	14.	8.	10.	9.	9.
10.	12.	7.	10.	9.	8.
12.	14.	9.	12.	10.	8.
14.	15.	10.	13.	12.	10.
12.	14.	9.	12.	8.	7.
12.	14.	9.	12.	10.	8.

mation of the first-in response time multiplied by the likelihood of zero busy vehicles, the second-in response time multiplied by the probability of 1 busy vehicle, and so on.

### Interpretation of Output

The CALL/CZSR routine provides the policymaker with three types of policy-related information: workload statistics, response time (or its travel time surrogate), and summary statistics for alternate vehicle site configurations.

The "percent of calls" figures (see Table 3.5) allows a user to calculate the workload range associated with a trial vehicle site configuration. The workload range is the difference in the percentage of calls between the vehicle responding to the most calls per day and the vehicle responding to the fewest. Experience has shown that the final site configuration will usually, but not always, have a smaller workload range than will the initial configuration. In the example (Table 3.5), the workload ranges for the initial and final configurations are 18.65 percent and 18.34 percent, respectively.

CALL/CZSR does reduce system mean response time. In the sample problem (Table 3.7), average response time is reduced from 5.355 minutes to 4.864 minutes. The set of

Table 3.12

**Portion of District Response Times  
for the CALL/CZSR Austin Run**

RESPONSE TIME BY DISTRICT

DIST. NO.	MINIMUM RESPONSE (MIN)	MEAN RESPONSE (MIN)
1	2.00	3.90
2	2.00	3.90
3	2.00	4.28
4	2.00	3.68
5	2.00	3.68
6	2.00	3.67
7	2.00	3.67
8	2.00	3.69
9	3.00	4.07
10	3.00	4.43
11	3.00	4.39
12	3.00	4.38
13	3.00	4.07
14	2.00	3.69
15	3.00	4.07
16	3.00	3.84
17	3.00	4.03
18	4.00	4.41
19	3.00	4.43
20	4.00	4.81
21	4.00	5.43
22	4.00	5.32
23	6.00	6.99
24	4.00	6.74
25	5.00	6.65
26	5.00	7.19
27	6.00	7.94
28	6.00	7.57
29	7.00	8.57
30	7.00	9.00
31	7.00	8.40
32	7.00	7.97
33	8.00	8.94
34	9.00	10.31
35	7.00	8.94
36	7.00	8.87
37	6.00	7.87
38	7.00	7.94
39	6.00	7.92
40	8.00	8.73
41	7.00	7.94
42	8.00	9.22
43	10.00	12.59
44	7.00	8.09
45	8.00	9.02
46	8.00	10.27
47	8.00	9.95
48	8.00	9.71
49	10.00	12.08

sites that reduces the mean response time to all calls for all system states also tends to lower response time in each individual state of system utilization. For example, if three vehicles are busy (see Table 3.7), the CALL/CZSR-selected configuration reduces the system mean response time from 6.960 minutes to 6.245 minutes.

Although CALL/CZSR may reduce average response time, any particular vehicle may perform worse in the final configuration than at its trial base, as measured in terms of expected response time to calls.

The first-in ambulance array shown in Table 3.10 can be used to generate a first-in map, as in Figure 3.2. This information is valuable in vehicle dispatch and provides a graphic representation of the area covered by each EMS vehicle.

### CALL/CZSR AS A POLICY TOOL

The CALL/CZSR program can be used to evaluate alter-

native locations for EMS vehicles. CALL/CZSR discriminates among alternative site configurations based on the average time for a system of EMS vehicles to respond to all calls for service. EMS policymakers may be interested in knowing how alternative facility site configurations perform relative to one another with respect to average system response time. Such a measure, along with economic, political, and social considerations, could influence the final deployment of EMS vehicles.

This section discusses how CALL/CZSR can be used to address the efficiency, equity, and effectiveness of an EMS system. Several CALL/CZSR runs will be discussed to illustrate policy uses of the results.

Efficiency may be defined as the ratio of service outputs to resource inputs. One facility site is more efficient than a second if the first uses fewer resources to yield the same output or if it achieves improved output using the same resource inputs. Decreased mean response time may be viewed as a system output while the number of vehicles in use is a measure of the resource inputs. CALL/CZSR identifies a site configuration that is more efficient than other site configurations in that the chosen sites yield improved service output using the same resource inputs.

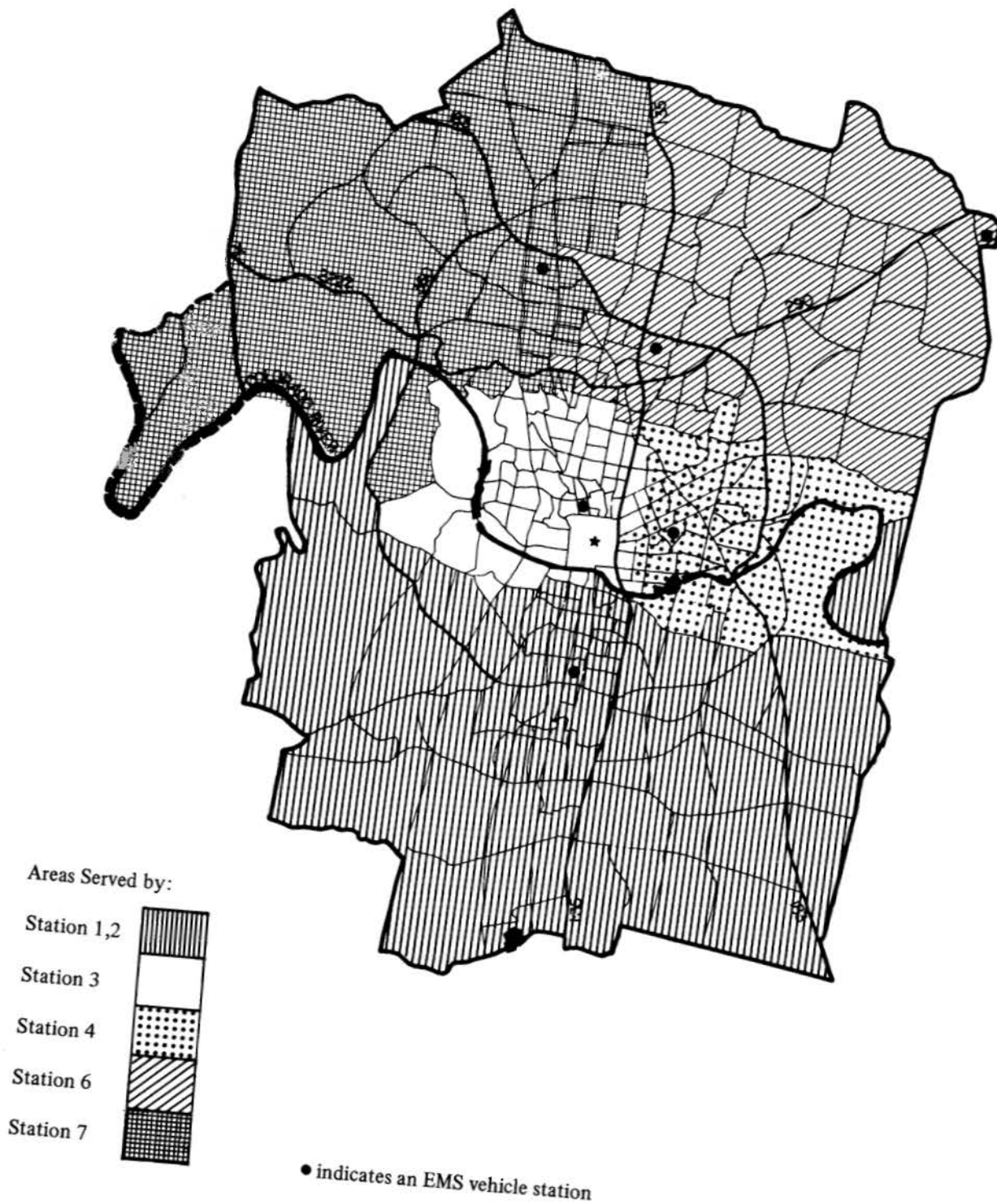
Response time can also measure the relative effectiveness of competing site configurations. Effectiveness reflects "how well the need for service is satisfied and the extent to which adverse impacts are avoided" (4). The response time measure is thought to be one measure of system effectiveness for emergency medical services because the likelihood of patient death or permanent disability from trauma is related to the length of delay prior to treatment (5).

The CALL/CZSR model can also evaluate the equity of staff workloads. A set of sites that permits nearly equal vehicle workloads is more equitable than a system in which one vehicle is constantly busy and others are idle. The objective of CALL/CZSR is not to equalize workloads. In practice, workloads tend to become more balanced as CALL/CZSR reduces system mean response time.

The objective of the CALL/CZSR model is to lower the average response time for the entire system, not to equalize the response times to all sites in the system. However, the program does print the mean response times of individual vehicles to each zone for both initial and final site configurations. This output provides information on the relative performance of a set of sites to the different geographical areas of the city. The difference in mean travel time between zones is a second measure of equity.

Policymakers are often influenced by factors other than efficiency, equity, and effectiveness. For example, the City Council of Austin has expressed the goal of increasing the joint use of public facilities. This goal suggests that EMS vehicles be sited on existing city properties, such as fire stations, when all other factors are equal. CALL/CZSR has

Figure 3.2  
First-In Service Areas of Six EMS Vehicles at Current Station Locations



been used in a cost-effectiveness analysis to evaluate the service tradeoffs when fire stations are used as EMS sites (6).

Finally, purely political considerations may enter into the decisionmaking process. Groups within the community may pressure officials to consider certain sites or to exclude sites from consideration. In its present form, the CALL/CZSR program can only partially incorporate these factors. Suppose that city officials determine that a zone is not appropriate as a base for an EMS vehicle, or alternatively, that it is necessary to locate a vehicle at a particular site. For CALL/CZSR to fix a site or to remove it from consideration, a programmer would have to modify the program and the input files to accommodate these complications. However, the CALL/CZSR program in its present form can evaluate any given site configuration if it is specified as the set of initial vehicle locations.

One caution in the use of CALL/CZSR is its heuristic nature; the program chooses a configuration having a "good" but not the "best" mean response time. Various initial deployments of EMS vehicles will yield different final configurations and different mean response times.

To illustrate the capabilities of CALL/CZSR, several analyses were done using data from the city of Austin. The number of vehicle sites was varied from four to ten vehicles using several initial sites as trial vehicle locations. Each set of sites used system parameters as outlined in Table 3.13.

When the initial sites were placed closer to the areas of largest demand, the program reached a solution relatively quickly. If the initial sites are not chosen wisely, a considerable amount of computer time can be used without arriving at a good solution. Also, as the number of ambulances increased, so did the number of evaluations performed. In fact, in 9 out of 13 runs the CALL/CZSR routine terminated after 300 search point evaluations and before it had reached the "best" solution.

**Table 3.13**

**System Parameters for Austin CALL/CZSR Runs**

Mean on-scene care time	15 minutes
Mean transfer time at hospital	20 minutes
Likelihood of transport	60 percent
Mean number of incidents per day	38
Number of hospitals	1
Number of zones	358

The average CALL/CZSR costs reflect the initial vehicle locations and the number of vehicles. The four, eight, and ten vehicle solutions used roughly 47 CPU seconds, 114 CPU seconds, and 160 CPU seconds respectively, on The University of Texas CDC Cyber 170/750 computer system. Most runs did not identify a stable configuration of sites; additional time and a larger iteration limit would be required to do so.

Figures 3.2 (see previous section), 3.3, and 3.4 show the vehicle first-in service areas for a configuration that was evaluated with CALL/CZSR. Figures 3.2 and 3.3 show an "islanding effect," or noncontiguous ambulance service zones. The source of this anomaly has not been identified. One possible explanation could be errors in the travel time matrix; another is the use of high-speed roads that permit unusually good access for a nearby EMS vehicle.

To further test CALL/CZSR, runs were performed using as initial sites (a) the current (January 1980) sites, and (b) six sites selected by the GAS program\* (see Tables 3.14 and 3.15). As might be expected, the locations selected by these programs with different objectives differed from each other and from the January 1980 EMS vehicle sites. However, one site (258) was chosen by the City, GAS, and CALL/CZSR.

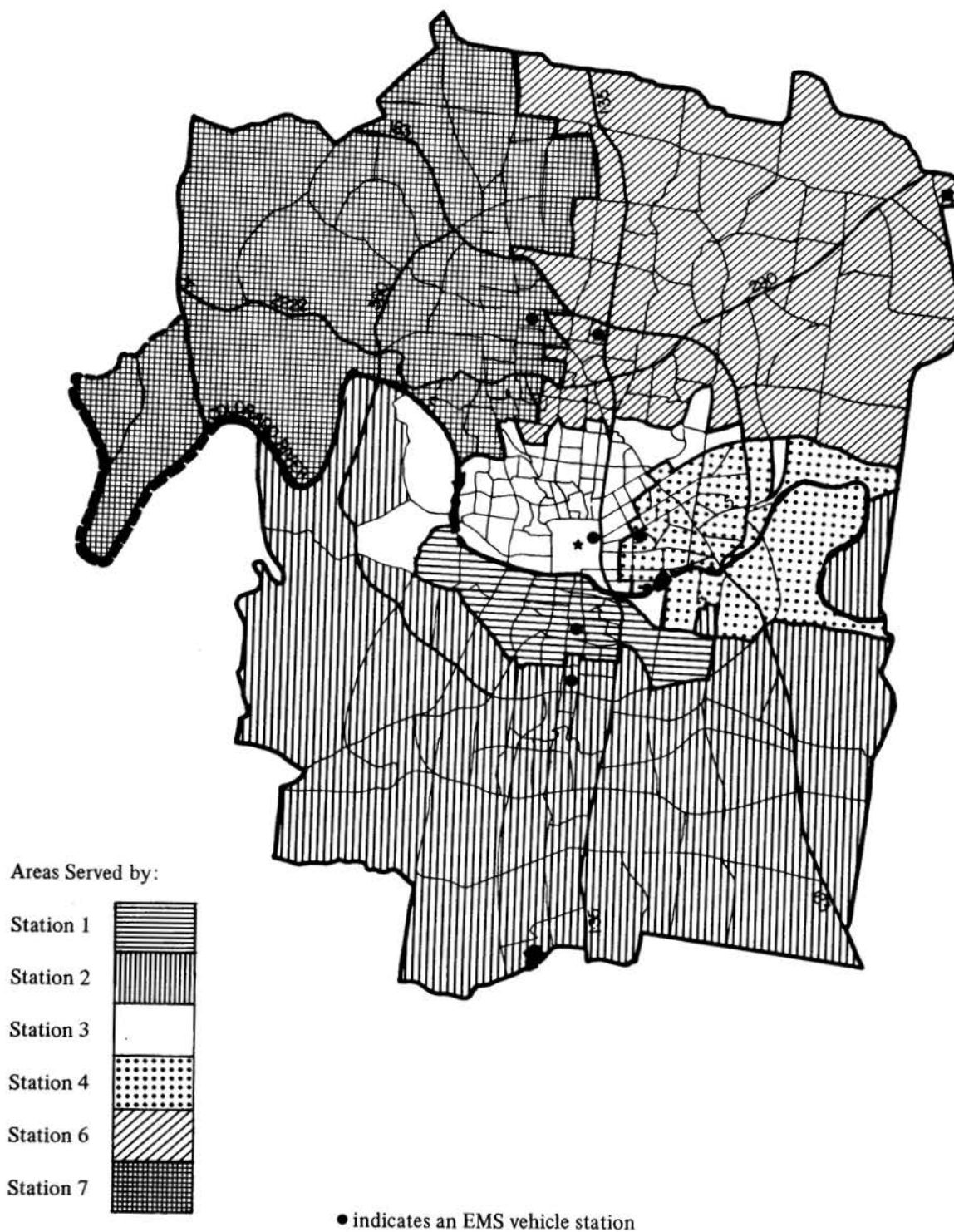
The results for the two programs can be seen on a zone-by-zone basis in Figures 3.2 through 3.4. A comparison of Figures 3.2 and 3.3 shows how well the current locations match the configuration for service areas generated by the CALL/CZSR model. The sites selected by CALL/CZSR when input from GAS was used indicate a different configuration of service areas. Figure 3.4 shows an eastern district with a boundary along the U.S. 183 corridor that does not occur in Figures 3.2 or 3.3. All configurations show similar southern service areas, and also a similar split of the northern side of town into two regions. However, the GAS configuration shows that split more nearly along I-35. The central city coverage area in each figure takes on a different shape.

Figure 3.5 indicates the response time for first-in vehicles located for the CALL/CZSR-improved station sites. This shows the areas of the city that can be covered within particular time intervals. The area having an average response time of less than 5 minutes is centered around the EMS vehicle sites in the southern, eastern, northern, and central regions. The 5 to 10 minutes response region encompasses most of the city. The service area with mean response time of eleven minutes or more includes 46 zones on the border of the Austin EMS service area.

\*The purpose of this run was to observe how the two programs could be used together. Robert Weeks conducted a separate CALL/CZSR policy analysis of alternative vehicle deployments (7).



Figure 3.3  
First-In Service Areas of Six EMS Vehicles Located at CALL/CZSR-Improved Sites



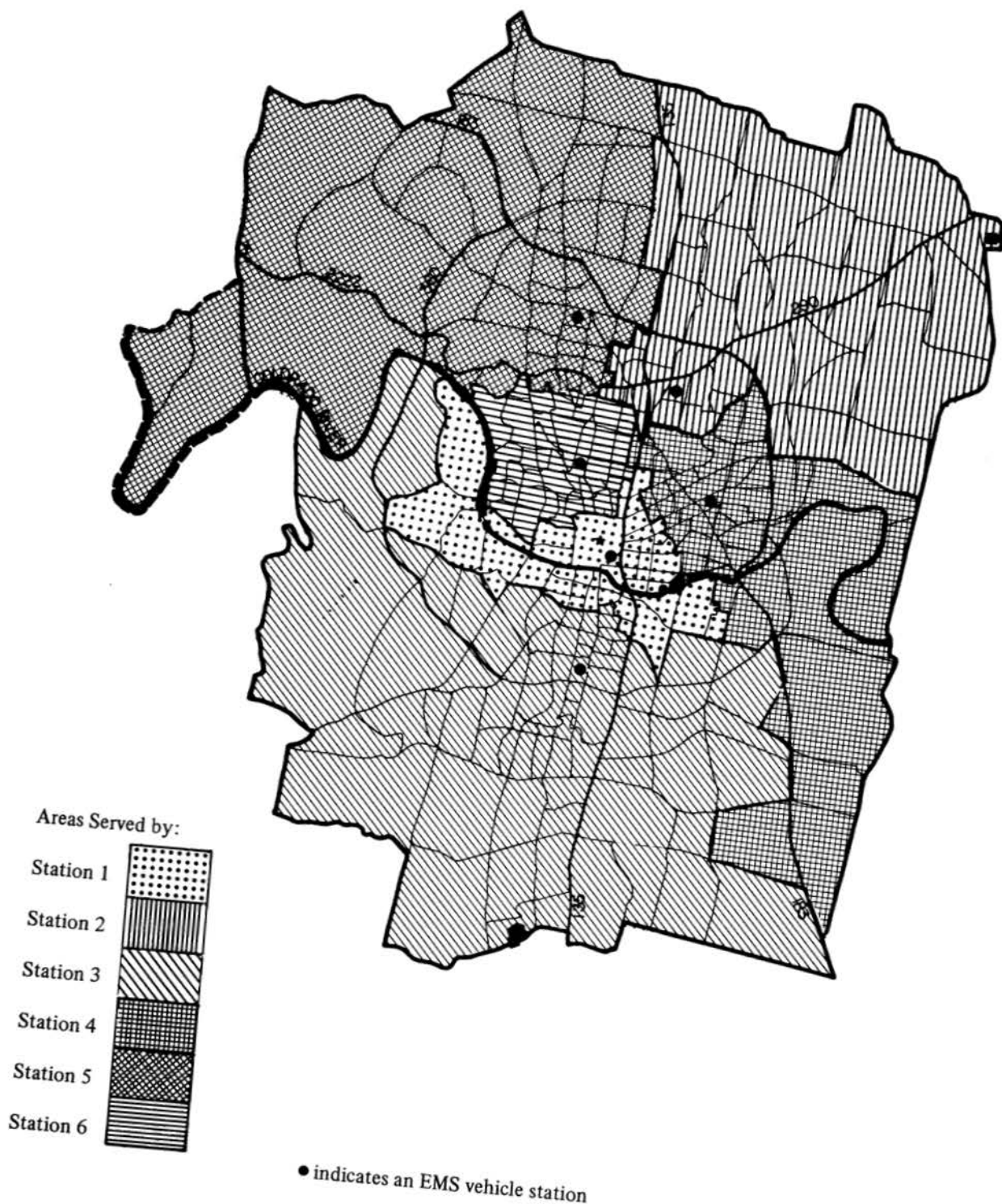
**Table 3.14**  
**Performance of EMS Vehicle Site Configurations**

<i>Criteria</i>	<i>Using Current Sites as Input</i>		<i>Using CLASGAS Solutions as Input</i>	
	<i>Initial</i>	<i>Final</i>	<i>Initial</i>	<i>Final</i>
System Mean Response Time (minutes)	5.355	4.917	4.877	4.816
Workload Range (percent)	18.65	18.33	17.12	15.51
Calls Served in Less Than: (percent)				
5 minutes	40.20	52.59	49.79	50.42
10 minutes	94.94	94.76	94.03	93.45
15 minutes	99.23	99.21	99.30	98.81

#### REFERENCES

- (1) James A. Fitzsimmons, "A Methodology for Emergency Ambulance Deployment," *Management Science* 19, no. 6 (February 1973): 627-36.
- (2) Emergency Medical Services Policy Research Project, *Location Techniques for Emergency Medical Service Vehicles, Volume II, Travel Time Data—Description and Assumptions* (Austin: LBJ School of Public Affairs, The University of Texas at Austin, 1979).
- (3) Ibid., *Volume III, Emergency Medical Service Calls in Austin—Description and Assumptions*.
- (4) E.S. Savas, "On Equity in Providing Public Services," *Management Science* 24, no. 8 (April 1978): 800-08.
- (5) P.G. Gaal, "Cardiac Arrest and Resuscitation," in *Early Management of Acute Trauma*, ed. A.M. Hahum (St. Louis: C.V. Moxby, 1966), pp. 53-63.
- (6) James A Fitzsimmons and Robert S. Sullivan, "Establishing the Level of Service for Public Emergency Ambulance Systems," *Socio-Economic Planning Sciences* 13, no. 5 (September 1979): 235-39.
- (7) Robert E. Weeks, College of Business, The University of Texas at Austin, "Options for the Deployment of EMS Vehicles Stations in Austin: An Analysis Using CALL/CZSR," report to Emergency Medical Services Policy Research Project.

Figure 3.4  
First-In Service Areas of Six EMS Vehicles  
Located at Station Sites Derived from GAS and CALL/CZSR Programs

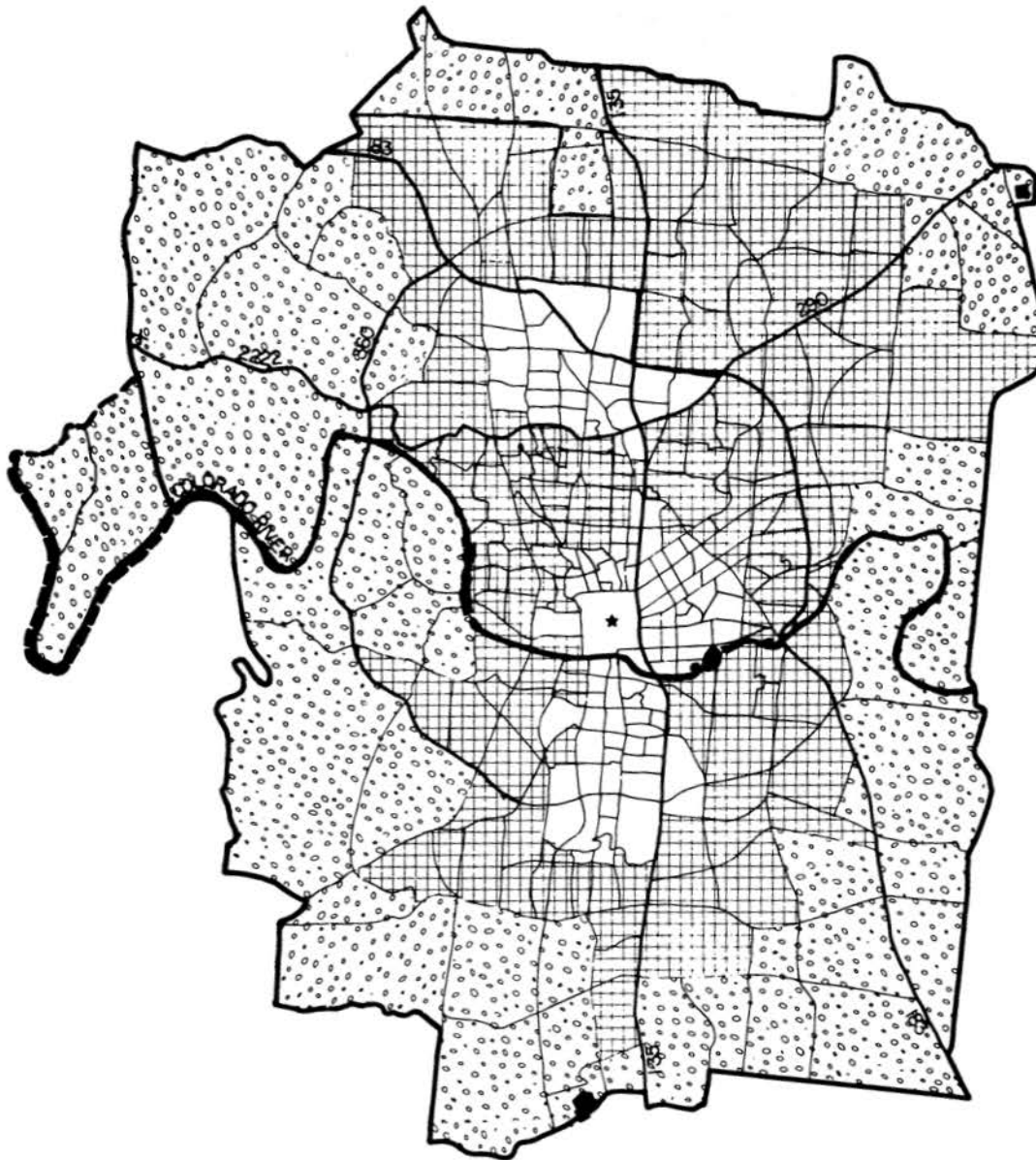




**Table 3.15**  
**Assignment and Performance of Ambulance Locations**

<i>Ambulance Number</i>	<i>Initial Zone Number</i>	<i>Initial Mean Response</i>	<i>Initial % of Calls</i>	<i>Final Zone Number</i>	<i>Final Mean Response</i>	<i>Final % of Calls</i>
Using current sites as input:						
1	258	6.78	15.88	238	6.50	16.37
2	258	7.31	10.78	258	7.64	10.34
3	59	6.64	27.96	54	6.65	28.67
4	180	6.06	21.44	179	5.84	19.31
5	152	9.92	14.64	112	10.04	14.92
6	118	11.48	9.31	111	11.23	10.34
Using GAS 6-vehicle solution as input:						
1	167	6.05	26.90	167	6.03	26.01
2	143	9.12	14.16	143	10.11	12.35
3	258	7.04	12.85	258	7.19	12.06
4	190	6.46	20.13	190	6.65	18.81
5	111	11.62	9.78	111	11.34	10.50
6	37	7.84	16.17	37	6.87	20.27

Figure 3.5  
 Mean Response Time by EMS Vehicles  
 Located at CALL/CZSR-Improved Station Sites  
 (6 vehicle solution)

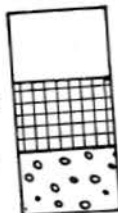


Areas Served in:

1 - 4 minutes

5 - 10 minutes

11 minutes or  
 greater



## APPENDIX

### Keypunching Instructions for CALL/CZSR

There are four types of cards in the input deck: job control cards, system parameter cards, hospital cards, and emergency medical vehicle cards. Figure 3.6 illustrates the input deck structure for the CALL/CZSR program.

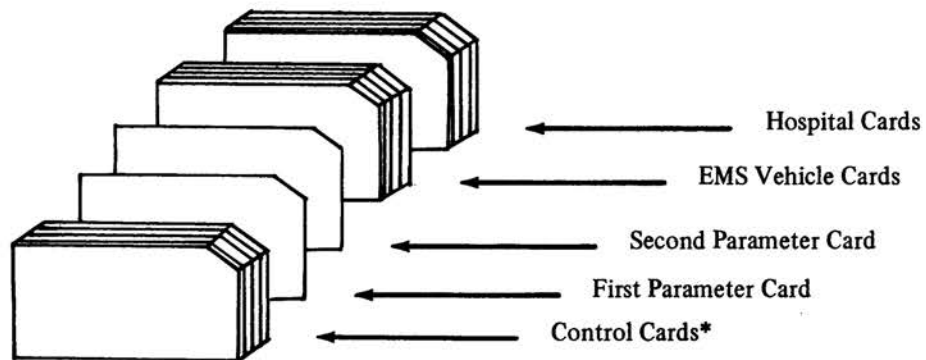
Table 3.16 lists the job control cards necessary to run CALL/CZSR on The University of Texas computer system. Table 3.17 shows the job control cards for the City of Austin computer.

The other card types are listed in Table 3.18, along with necessary keypunching instructions. All real number para-

meters (see first parameter card) may be punched anywhere in the card column field and must include a decimal point. Each integer parameter must be punched right justified in its card column field, with no decimal point (see second parameter card).

Each hospital to which EMS patients are to be transported and each EMS vehicle requires a corresponding card in the input deck. The numerical data on these cards must be punched right justified in the card column fields.

Figure 3.6  
Structure of CALL/CZSR Input Deck



\*Indicate a requirement for control cards. The nature and placement of these cards will be unique to each computer system.

Table 3.16

**CALL/CZSR Control Card Requirements  
for The University of Texas at Austin Computer System**

[User Identification Card]

[Password Card]

JOB, PR=30, TM=200

PEADCCF B635 EMS2

---

In the event that the EMS2 macro is lost or erased, the user should replace the preceding card with the following cards:

READPF B635 CONTIG MATT

READPF 7816 TRAVELT

RENAME CONTIG=TAPE7

RENAME MATT=TAPE8

RENAME TRAVELT=TAPE9

READPF 2075 MOTI

RFL 220000

MNF I=MOTI, B=MOTIX, L=LI

MOTIX

---

[7/8/9 multipunch]

[System parameter cards]

[Emergency medical facility cards]

[Emergency medical vehicle cards]

[6/7/8/9 multipunch]

Table 3.17

**CALL/CZSR Control Card Requirements for  
the City of Austin Computer System**

[User Job Card]

```
//JOB LIB DD DSN=USER1.LINKLIB,DISP=SHR
// DD DSN=CITY1.LINKLIB,DISP=SHR
//S01 EXEC PGM=IEBGENER
//SYSIN DD DUMMY
//SYS PRINT DD SYSOUT=A
//SYSUT2 DD DSN=EM.SURG,UNIT=DISK,DISP=(NEW,PASS),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200),SPACE=(CYL,(2,1))
//SYSUT1 DD*
```

Zone Incident Count Cards

```
/*
//SYSOUT DD SYSOUT=A
//ST1 EXEC PGM=EM4000F
//SYSOUT DD SYSOUT=A
//FT08F001 DD DSN=EM.SURG,DISP=(OLD,DELETE),UNIT=DISK
//FT09F001 DD DSN=EM.MATRX1,UNIT=TAPE,LABEL=(,SL),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=8000),VOL=SER=001031
//FT07F001 DD DSN=EM.CONTIG,UNIT=TAPE,LABEL=(,SL),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=19040),VOL=SER=001243
//FT05F001 DD *
```

[System Parameter Cards]

[Emergency Medical Facility Cards]

[Emergency Medical Vehicle Cards]

```
/*
```

```
//FT06F001 DD SYSOUT=A
```

```
//
```

**Table 3.18**  
**CALL/CZSR Card Specifications**

<i>Card Type</i>	<i>Variable</i>	<i>Card Column</i>	<i>Sample Value</i>	<i>Definition</i>	<i>Comments</i>
First parameter card	LAMBDA	1- 8	38.0	Average number of calls per day	
	CARE	9-16	15.0	Average time on scene	Given in minutes
	TRSFR	17-24	20.0	Average transfer time at hospital	Given in minutes
	TRANS	25-32	0.60	Percent of calls requiring transport to hospital	Given in decimal form
	DECI	33-40	1.0	Conversion factor from an actual travel time to an integer representation, using some power of ten	As an example, if travel time is given to the nearest hundredth of a minute, a value of 100.0 should be used
Second parameter card	LIMIT	1- 5	300	Maximum number of search evaluations	Maximum value = 999
	NAMB	9-13	6	Number of EMS vehicles in fleet	Maximum value = 10
	NHOSP	17-21	1	Number of emergency medical facilities	Maximum value = 10
	NDIST	25-29	358	Number of districts (zones) in the service area	Maximum value = 400
	NFRAC	33-37	30	Number of one-minute class intervals desired in the call response distribution output	CALL/CZSR generates such distributions for cumulative and relative frequencies Maximum value = 30
Emergency medical facility cards	EMF	1-12	BRACKENRIDGE	The emergency medical facility name	
	HOSLOC	13-17	055	The district (zone) number in which the emergency medical facility is located	
Emergency medical	AMBNO	1-5	1	An identification number for the emergency medical vehicle	
	TYPE	6-10	1	The EMS vehicle type	"1" indicates a surface vehicle "2" indicates an air vehicle
	AMBSITE	11-15	258	The district (zone) number in which the emergency medical vehicle is initially located	



## Chapter 4

# A Manual for Users of the GAS Program

Decisions on the deployment of emergency medical vehicles in a city often involve competing public interests. A person with a propensity for heart attacks might wish EMS vehicles to be based at sites that could reach his/her residence or place of work within some upper bound on response time. A member of the City Council might wish the system to use few resources, but yet be capable of providing some "acceptable" level of service. A neighborhood leader might wish to ensure that his/her area of the city would receive better services as compared to others. Different people have biases about priorities among these and other EMS system goals. One of the advantages of certain computer programs is that they allow the user to observe how these goals affect deployment and how selected sites impact each of the interested groups. The GAS program can be used both to generate good sets of potential EMS vehicle bases that can serve different goals and to evaluate the impacts of a proposed deployment.

GAS is a computer program developed by Richard Church (1) to solve a variant (2) of the Maximal Covering Location Problem (3). It uses two subprograms, GA and GAS, to find a fixed number of sites in a region that can maximize the fraction of users that will be served within a desired response time. The GA program selects as the first site that potential vehicle location which covers the largest fraction of demand. The second site picked covers the largest fraction of demand not covered by the first site, and so on. It is possible that a site added to the solution set in an early iteration may not be justified later due to subsequent selection of other sites. So, at each iteration, the GAS program seeks to replace each site in the solution set one-at-a-time with another site which would improve overall demand coverage. This process is continued until all demand is covered or until the number of selected locations equals the number of sites specified by the user. This procedure is flexible enough to use different measures of "demand" and "coverage."

GAS can be used to find various efficient or equitable vehicle deployments. Efficiency is often measured as the ratio of service outputs to service inputs. One EMS system configuration would be more efficient than another if it involved a smaller number of vehicles (input) to cover an equal number of calls (output). Equity can be defined as equality of service. For EMS service, there exist different types of users from whom a decisionmaker might seek equitable services. Equity could be related to the user's location (place in a city), ethnic origin, age, or incident type (heart attack, gunshot wound, etc.). GAS is able to address

each of these problems by varying the definition of "demand" and "coverage."

The strength of GAS is that it finds the set of P sites able to reach the "largest" fraction of defined EMS demand. One of its weaknesses is that GAS does not consider the queuing pattern of calls.

This chapter explains the way in which the GAS program operates and identifies the assumptions inherent in the model. To familiarize the reader with the mechanics of GAS, a sample run illustrates the required data inputs and outputs. This illustration was developed from data used by the City of Austin's Department of Emergency Medical Services in improving the performance of their system.

### GAS ASSUMPTIONS AND INPUTS

To apply the GAS program to emergency medical services, the user must first collect data related to EMS demand, vehicle travel time, and other characteristics. There exist a variety of EMS demand surrogates. A user may seek to design the system to cover all calls for service, only critical calls, or those requiring transport to a hospital. Table 4.1 lists various demand surrogates and their respective data sources. The user must also provide a measure of travel times between areas. The Austin study used the travel time matrix calculated by the Austin Transportation Study Office (4). In addition, a user must select (a) the number of vehicles to be sited by the program and (b) some measure for effectiveness, such as primary and secondary maximum response times. The primary response time defines whether or not a vehicle site can "cover" demands in other zones. The potential coverage strongly affects the locations selected by the program. The secondary response time is used for tabulating purposes only and does not affect vehicle location.

A user can specify the problem context further by fixing certain locations as vehicle sites, eliminating some sites from consideration as vehicle bases, or selecting to use either the GA or GAS routine.

The GAS assumptions concerning demand and the characteristics of emergency medical services appear in Table 4.2. A detailed description of these assumptions is presented in Volume I of the 1978-79 EMS Policy Research Project Report (5).

### SAMPLE RUN

This section illustrates the use of the GAS program in

**Table 4.1**  
**GAS Demand Surrogates**

<i>Demand Surrogate</i>	<i>Source</i>	<i>Limitations</i>
expected call frequency	City of Austin Department of Emergency Medical Services records of calls from December 1976, January, June, July, and August, 1977.	call pattern changes after 1976/1977
transport cases		limited sample size
nontransport cases		
critical calls		
noncritical calls		
total population	1976 Special Census of the U.S. Bureau of the Census	changes in population after 1976
Black population		
Spanish-surname population		data not available for outlying county serial zones
population under 18		
population over 65		

selecting good emergency medical service vehicle sites in Austin. The sample program uses the GAS option of the GAS program to identify four ambulance sites that maximize coverage of critical calls within a five-minute primary service time. The required data are provided to the GAS program on sets of computer cards: job control cards, master cards, demand data cards, problem cards, and constraint cards. Figure 4.1 illustrates the general card deck structure for solving GAS problems using The University of Texas computer system. Table 4.3 lists program parameters and keypunching instructions for GAS.

Job control cards are installation-specific instructions that tell the computer to perform various functions. The job control cards listed in the appendix can be used to solve the sample problem on either the City of Austin computer (Table 4.8) or The University of Texas computer (Table 4.9).

The GAS program uses two master cards to indicate parameters for a specific run. The first card lists data on the number of potential facility sites in the study area, whether or not demand weights are to be read, and whether the travel time is read in the form of a matrix or as (x,y) coordinates. The sample problem uses demand weight cards and an external tape of travel time data. The second master card specifies whether special constraints appear in the subsequent data cards and whether to use the GA or GAS selection procedures. No special constraints are used in the GAS sample run. Key punching instructions for both master cards are given in Table 4.3.

The demand data cards consist of weights representing each zone's demand for EMS. The sample run uses the frequency of critical calls in each of 358 zones. Each card may contain weights for ten zones; hence, the sample run uses 36 cards to list the demands from 358 serial zones. The end of the demand data is signified by another installation specific job control card.

Two problem cards follow the demand deck. The first can be used to state a title of the problem and the second indicates the value of certain parameters: (a) the number of facilities to be sited; (b) the primary service time in whole minutes; (c) the secondary service time in whole minutes; and (d) whether or not special constraints are used. For the sample run, four facilities are sited to cover calls within a five-minute primary service time. Ten minutes is the secondary service time and no special constraints are used in the sample problem.

Special constraint cards are included when a user wishes to fix and/or eliminate potential vehicle sites from consideration. The first constraint card indicates the total number of sites to be fixed. Cards listing fixed zone numbers precede cards specifying those zones to be eliminated from consideration. Only one zone is keypunched per card.

Two blank cards complete the GAS data deck. A computer-specific job control card follows to end the program.

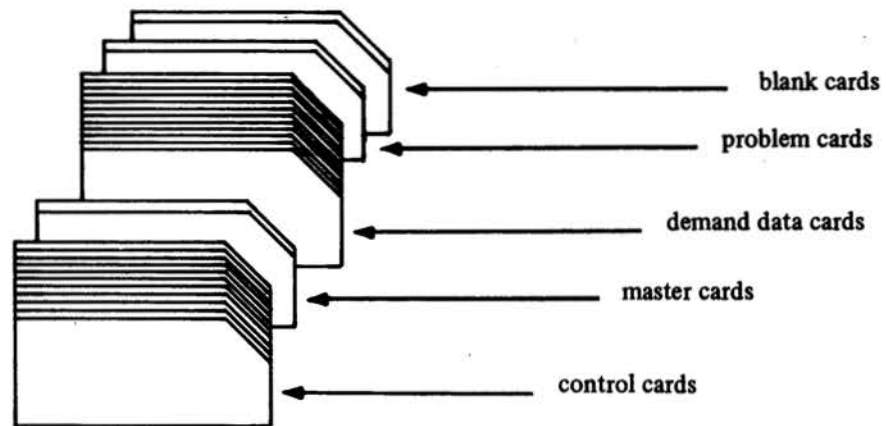
## PROGRAM RESULTS

After GAS lists the demand data used in the problem, it

**Table 4.2**  
**GAS Assumptions**

<i>Subject</i>	<i>Model Assumptions</i>	<i>Austin Sample Application Assumptions</i>
study area	set of discrete zones represented by centroid points connected by travel time links	set of 358 transportation serial zones represented by centroids connected by travel time links
potential vehicle sites	any zone centroid	any zone's centroid of population concentration
origin of calls for EMS service	any zone centroid	any zone's centroid of population concentration
demand for EMS service	some measure of "demand"	the number of critical calls that occurred in each serial zone during December 1976 and January, June, July, and August of 1977
vehicle characteristics	all vehicles are identical in speed of response and equipment	all vehicles are identical in speed of response and equipment
personnel characteristics	personnel have equal expertise	EMS personnel have equal expertise
vehicle availability	a vehicle can respond to any call	four vehicles can respond to any call
vehicle dispatch	closest available vehicle is dispatched	closest available vehicle is dispatched
interzonal travel times	interzonal travel may be measured either in time or distance terms	interzonal travel times
GAS objective	locate vehicles so as to maximize coverage of demand within a minimum response time	locate vehicle sites to maximize coverage of Austin's critical calls within a five minute response time
measure of effectiveness	maximum response time	maximum response time
termination of GAS routine	occurs if all demand is covered or if maximum number of vehicles are sited	occurs if all calls are covered or if maximum number of vehicles are sited

**Figure 4.1**  
**GAS Deck Structure**



finds the site that covers the largest fraction of the critical calls. The site, serial zone 9 in the example, can cover some zones and cannot cover others. Table 4.4 lists the serial zones that are either covered or not covered within five minutes. The term "population" means "demand surrogate"; total critical calls is the surrogate in the sample run. Tables 4.5, 4.6, and 4.7 record the vehicle sites and service areas chosen on successive iterations.

At every iteration the output lists the fraction of demand covered and the areas of service (the serial zones) of each chosen vehicle base. Table 4.4 indicates that zone 9 covers 403 critical calls or 39.24 percent of the critical calls within five minutes. The second iteration adds zone 101 to

zone 9; together these bases can reach 55.11 percent of Austin's critical calls. Iteration three adds zone 190, which increases coverage to 65.34 percent (see Table 4.5). Note that GAS substitutes zone 10 for zone 9. This is illustrated in Table 4.6. GAS reviews each chosen site to see if a substitution will increase coverage. For a three-vehicle solution, a base in zone 9 can be replaced by zone 10; coverage increases from 65.34 to 65.82 percent. Substitution appears again in the fourth iteration. After selecting zone 258 as the final facility location, GAS opts to replace zone 10 with zone 52 to increase critical call coverage from 74.20 to 74.78 percent (see Table 4.7).

## REFERENCES

- (1) Richard L. Church, *An Introduction and Guide to the Location of Public Facilities Utilizing the "GAS" Program* (Austin: LBJ School of Public Affairs, The University of Texas at Austin, 1979).
- (2) David Eaton, Richard L. Church, Vivienne L. Bennett, Bryan Hamon, and Luis G. Valencia Lopez, "On Deployment of Health Resources in Rural Valle del Cauca, Colombia," in *Planning and Development Processes in the Third World*, ed. Wade Cook (New York: North Holland Publishing Co., 1981).
- (3) Richard L. Church and Charles S. ReVelle, "The Maximal Covering Location Problem," *Papers of the Regional Science Association* 32, no. 101 (Fall 1974): 101-18.
- (4) Lyndon B. Johnson School of Public Affairs, *Location Techniques for Emergency Medical Service Vehicles, Volume II: Travel Time Data-Descriptions and Assumptions* Policy Research Project Report No. 34 (Austin: LBJ School of Public Affairs, The University of Texas at Austin, 1979).
- (5) Ibid., *Volume I: An Analytical Framework for Austin, Texas*.

**Table 4.3**  
**GAS Electives and Keypunching**

<i>Card Set</i>	<i>Card Number</i>	<i>Definition</i>	<i>Columns</i>	<i>Value</i>	<i>Value in Sample Run</i>	<i>Comments</i>
MASTER	1	Specifies Parameters:				
		number of potential facility sites in study area	1-5	integer variable	358	integer numbers are punched right-justified in the appropriate field
		number of demand points in study area	6-10	integer variable	358	
		whether or not demand weights are read	20	1 if read; 0 if not read	1	
		whether the travel time is read in the form of a matrix or (x,y) coordinates	25	if matrix; 0 if (x,y) coordinates	1	
	2	Specifies Parameters:				
		whether special constraints are used	20	1 if used; 0 if not used	0	
DEMAND DATA	1	Assigns Demand Weights to Zones:				
		value assigned to zone number 1	1-8	decimal number	1.000	ten demand nodes per card
		value assigned to zone number 2	9-16	decimal number	5.000	
		•	•	•	•	
		•	•	•	•	
		value assigned to zone number 10	73-80	decimal number	1.000	each demand weight has a decimal point
	2	value assigned to zone number 11	1-8	decimal number	1.000	
		•	•	•	•	
		•	•	•	•	
	36	value assigned to zone number 358	57-65	decimal number	0.000	
PROBLEM CARDS	1	Name of Program	1-80	variable	Critical Call History	any alphanumeric name acceptable
	2	Specifies Parameters:				
		number of facilities to be sited in the city	1-5	integer variable	4	
		maximal service time in whole minutes	6-15	integer variable	5	
		secondary service time in whole minutes	16-25	integer variable	10	
		special constraint features	55	1 if used; 0 if not used	0	

Table 4.3 (continued)

<i>Card Set</i>	<i>Card Number</i>	<i>Definition</i>	<i>Columns</i>	<i>Value</i>	<i>Value in Sample Run</i>	<i>Comments</i>
CONSTRAINT CARDS (optional)	1	Specifies Values For:				
		total number of zones eliminated as potential sites	1-4	integer variable	na	use of X and Y indicates that the number of cards is variable
		total number of zones which are fixed as sites	11-14	integer variable	na	
	2 to X	zone eliminated	1-4	zone index number	na	no sites were fixed or eliminated in the sample run
	3	zone eliminated	1-4	zone index number	na	
	•	•	•	•	•	
	•	•	•	•	•	
	•	•	•	•	•	
	X	zone eliminated	1-4	zone index number	na	
	(X+1)	zone fixed	1-4	zone index number	na	
	(X+2)	zone fixed	1-4	zone index number	na	
	•	•	•	•	•	
	•	•	•	•	•	
	•	•	•	•	•	
	Y	zone fixed	1-4	zone index number	na	



Table 4.4  
Initial GAS Solution in Sample Problem

ITERATION NUMBER, 1

NUMBER OF FACILITIES 1  
SERVICE DISTANCE = 5.000

NEW FACILITY LOCATION NUMBER 9

FACILITIES ARE LOCATED AT 9,

POPULATION SERVED 403.00 PERCENT OF TOTAL POPULATION SERVED 39.24

NUMBER OF FACILITIES=4, SERVICE TIME=5.0, SC3=0.0

FACILITIES ARE LOCATED AT 9,  
PRIMARY DISTANCE = 5.00  
SECONDARY DISTANCE = 0.00

```
*****
*          *PRIMARY*SECONDARY*POPULATION*POPULATION*LARGEST,*          *MT,DIST*MT,DIST, *MT,DIST* TOTAL *
PARTITION*FACILITY*SERVED * SERVED * OUTSIDE * IN *TRAVELED* NODE *PRIMARY*SECONDARY*OUTSIDE*WEIGHTED*
NUMBER * NUMBER * POP, * POP, *SECONDARY *PARTITION *DISTANCE*NUMBER*COVERED* COVERED *PRIMARY*DISTANCE*
1          9  403.00  234.00  390.00  1027.00  32.0  342  1536.0  1579.0  6119.0  7655.0
*****
          403.00  234.00  390.00  1027.00  1536.0  1579.0  6119.0  7655.0
PARTITION 1 FACILITY 9
** 1 D= 2.00** 2 D= 1.00** 3 D= 2.00** 4 D= 1.00** 5 D= 1.00** 6 D= 1.00
** 7 D= 1.00** 8 D= 1.00** 9 D= 1.00** 10 D= 1.00** 11 D= 1.00** 12 D= 1.00
** 13 D= 1.00** 14 D= 1.00** 15 D= 2.00** 16 D= 1.00** 17 D= 1.00** 18 D= 1.00
** 19 D= 1.00** 20 D= 1.00** 21 D= 2.00** 22 D= 2.00** 23 D= 4.00** 24 D= 4.00
** 25 D= 4.00** 26 D= 5.00** 27 D= 6.00** 28 D= 5.00** 29 D= 6.00** 30 D= 7.00
** 31 D= 6.00** 32 D= 5.00** 33 D= 8.00** 34 D= 8.00** 35 D= 7.00** 36 D= 7.00
** 37 D= 7.00** 38 D= 7.00** 39 D= 6.00** 40 D= 8.00** 41 D= 7.00** 42 D= 9.00
** 43 D= 10.00** 44 D= 9.00** 45 D= 9.00** 46 D= 11.00** 47 D= 12.00** 48 D= 11.00
** 49 D= 13.00** 50 D= 14.00** 51 D= 2.00** 52 D= 2.00** 53 D= 2.00** 54 D= 3.00
** 55 D= 2.00** 56 D= 4.00** 57 D= 4.00** 58 D= 3.00** 59 D= 3.00** 60 D= 4.00
** 61 D= 4.00** 62 D= 5.00** 63 D= 5.00** 64 D= 5.00** 65 D= 4.00** 66 D= 5.00
** 67 D= 6.00** 68 D= 4.00** 69 D= 4.00** 70 D= 5.00** 71 D= 4.00** 72 D= 6.00
** 73 D= 6.00** 74 D= 7.00** 75 D= 6.00** 76 D= 7.00** 77 D= 6.00** 78 D= 7.00
** 79 D= 8.00** 80 D= 8.00** 81 D= 9.00** 82 D= 9.00** 83 D= 9.00** 84 D= 9.00
** 85 D= 10.00** 86 D= 10.00** 87 D= 10.00** 88 D= 9.00** 89 D= 8.00** 90 D= 7.00
** 91 D= 7.00** 92 D= 6.00** 93 D= 7.00** 94 D= 9.00** 95 D= 8.00** 96 D= 8.00
** 97 D= 9.00** 98 D= 10.00** 99 D= 9.00** 100 D= 10.00** 101 D= 10.00** 102 D= 10.00
** 103 D= 11.00** 104 D= 10.00** 105 D= 10.00** 106 D= 11.00** 107 D= 13.00** 108 D= 12.00
** 109 D= 11.00** 110 D= 11.00** 111 D= 12.00** 112 D= 10.00** 113 D= 11.00** 114 D= 12.00
** 115 D= 12.00** 116 D= 13.00** 117 D= 13.00** 118 D= 14.00** 119 D= 13.00** 120 D= 16.00
** 121 D= 16.00** 122 D= 16.00** 123 D= 14.00** 124 D= 14.00** 125 D= 19.00** 126 D= 15.00
** 127 D= 4.00** 128 D= 5.00** 129 D= 5.00** 130 D= 6.00** 131 D= 6.00** 132 D= 9.00
** 133 D= 6.00** 134 D= 6.00** 135 D= 6.00** 136 D= 9.00** 137 D= 9.00** 138 D= 9.00
** 139 D= 7.00** 140 D= 6.00** 141 D= 8.00** 142 D= 9.00** 143 D= 9.00** 144 D= 10.00
```

Table 4.5  
GAS Iteration 3 in Sample Problem

```

ITERATION NUMBER,      3
NUMBER OF FACILITIES    3
SERVICE DISTANCE =    5,888
NEW FACILITY LOCATION NUMBER  198
FACILITIES ARE LOCATED AT    9, 181, 198,
=====
POPULATION SERVED    671,88    PERCENT OF TOTAL POPULATION SERVED    65.34
=====

```

Table 4.6  
First GAS Substitution in Sample Problem

SUBSTITUTION ALGORITHM USED

NODE 10 REPLACES FACILITY LOCATION 9  
THIS IS NOW FACILITY NUMBER 1

FACILITIES ARE LOCATED AT 10, 101, 190,

POPULATION SERVED 676,00 PERCENT OF TOTAL POPULATION SERVED 65,82

NUMBER OF FACILITIES=4, SERVICE TIME=5,0, SCB=0,0

FACILITIES ARE LOCATED AT 10, 101, 190,

PRIMARY DISTANCE = 5,00

SECONDARY DISTANCE = 0,00

PARTITION		FACILITY	SERVED	POP.	SECONDARY	POPULATION	POPULATION	LARGEST	TRAVELED	NODE	PRIMARY	SECONDARY	OUTSIDE	HEIGHTED	TOTAL
NUMBER	NUMBER	POP.	POP.	POP.	PARTITION	DISTANCE	NUMBER	COVERED	COVERED	PRIMARY	DISTANCE				
1	10	351,00	109,00	59,00	519,00	21,0	323	1325,0	741,0	1309,0	2714,0				
2	101	165,00	90,00	52,00	307,00	29,0	342	607,0	430,0	1214,0	1981,0				
3	190	160,00	34,00	7,00	201,00	19,0	321	563,0	233,0	305,0	860,0				
PARTITION 1		FACILITY 10	676,00	233,00	110,00	1027,00		2575,0	1604,0	2900,0	5403,0				

1 D=	2,00**	2 D=	2,00**	3 D=	2,00**	4 D=	1,00**	5 D=	1,00**	6 D=	1,00
7 D=	2,00**	8 D=	1,00**	9 D=	1,00**	10 D=	1,00**	11 D=	1,00**	12 D=	1,00
13 D=	1,00**	14 D=	2,00**	15 D=	2,00**	16 D=	2,00**	17 D=	1,00**	18 D=	1,00
19 D=	1,00**	20 D=	1,00**	21 D=	1,00**	22 D=	1,00**	23 D=	3,00**	24 D=	3,00
25 D=	4,00**	26 D=	5,00**	27 D=	5,00**	28 D=	5,00**	29 D=	6,00**	30 D=	7,00
31 D=	5,00**	32 D=	5,00**	33 D=	7,00**	34 D=	8,00**	35 D=	7,00**	36 D=	6,00
37 D=	6,00**	38 D=	7,00**	39 D=	5,00**	51 D=	2,00**	52 D=	2,00**	53 D=	2,00
54 D=	3,00**	55 D=	2,00**	56 D=	4,00**	57 D=	4,00**	58 D=	3,00**	59 D=	3,00
60 D=	4,00**	61 D=	4,00**	62 D=	5,00**	63 D=	5,00**	64 D=	5,00**	65 D=	6,00
66 D=	5,00**	67 D=	6,00**	68 D=	4,00**	69 D=	4,00**	71 D=	6,00**	72 D=	6,00
75 D=	6,00**	127 D=	4,00**	162 D=	4,00**	163 D=	3,00**	164 D=	4,00**	165 D=	3,00
166 D=	2,00**	167 D=	2,00**	168 D=	3,00**	169 D=	4,00**	170 D=	4,00**	171 D=	3,00
172 D=	3,00**	173 D=	4,00**	174 D=	5,00**	175 D=	5,00**	176 D=	6,00**	178 D=	4,00
203 D=	4,00**	204 D=	4,00**	205 D=	5,00**	206 D=	5,00**	207 D=	6,00**	208 D=	5,00
209 D=	5,00**	210 D=	5,00**	211 D=	6,00**	212 D=	7,00**	213 D=	8,00**	214 D=	7,00
215 D=	7,00**	216 D=	9,00**	217 D=	6,00**	218 D=	9,00**	220 D=	9,00**	229 D=	12,00
230 D=	10,00**	231 D=	8,00**	232 D=	2,00**	233 D=	3,00**	234 D=	3,00**	235 D=	4,00
236 D=	5,00**	237 D=	4,00**	238 D=	5,00**	239 D=	3,00**	240 D=	3,00**	241 D=	4,00
242 D=	6,00**	243 D=	5,00**	244 D=	5,00**	245 D=	7,00**	246 D=	10,00**	247 D=	10,00
248 D=	13,00**	249 D=	8,00**	250 D=	9,00**	251 D=	6,00**	252 D=	8,00**	253 D=	8,00
254 D=	6,00**	255 D=	5,00**	256 D=	6,00**	257 D=	7,00**	258 D=	7,00**	259 D=	7,00
260 D=	9,00**	261 D=	8,00**	262 D=	9,00**	263 D=	9,00**	264 D=	10,00**	265 D=	9,00
266 D=	12,00**	272 D=	9,00**	273 D=	12,00**	274 D=	10,00**	275 D=	14,00**	302 D=	15,00

Table 4.7  
Final GAS Substitution in Sample Problem

```

ITERATION NUMBER,      4
NUMBER OF FACILITIES    4
SERVICE DISTANCE =     5,000
NEW FACILITY LOCATION NUMBER  250
FACILITIES ARE LOCATED AT  10, 101, 190, 250,
-----
POPULATION SERVED      742,00      PERCENT OF TOTAL POPULATION SERVED  74,20
-----
SUBSTITUTION ALGORITHM USED
NODE      52 REPLACES FACILITY LOCATION      10
THIS IS NOW FACILITY NUMBER      1
FACILITIES ARE LOCATED AT  52, 101, 190, 250,
-----
POPULATION SERVED      746,00      PERCENT OF TOTAL POPULATION SERVED  74,70
-----

```



## APPENDIX

Tables 4.8 and 4.9 list the control cards used at the City of Austin and The University of Texas, respectively.

**Table 4.8**  
**City of Austin Computer Job Control Cards**

Card Number	Keypunch Sequence on Card†												
	1	5	0	5	0	5	0	5	0	5	0	5	0
1	(user number and name)												
2	// JOBLIB DD DSN=CITY1.TESTLIB,DISP=SHR												
3	// DD DSN=USER1.LINKLIB,DISP=SHR												
4	// EXEC PGM=GAS2												
5	// FT06F001 DD SYSOUT=A												
6	// FT05F001 DD *,DCB=BLKSIZE=8000												
	[master and demand decks]												
7	/*												
8	// DD DSN=EM.MATRX1,UNIT=TAPE,DISP=(OLD,KEEP),LABEL=(,SL),												
9	// DCB=(RECFM=FB,FRECL=80,BLKSIZE=8000),VOL=SER=001031												
10	// DD *												
	[problem and blank cards]												
11	/*												
12	//												

†The text on each control card should be punched in the column shown. The use of brackets and lower case letters indicates that a deck of computer cards should be keypunched according to the format guide of Table 4.3.

**Table 4.9**  
**University of Texas Computer Job Control Cards**

Card Number	Keypunch Sequence on Card†										
	1	5	0	5	0	5	0	5	0	5	0
1	(user number and name)										
2	(password)										
3	JOB, TM=200, PR=100										
4	READPF 3473 GASPAC										
5	READPF 7816 TTM358										
6	COPYBR INPUT TAPE1										
7	COPYBR TTM358 TAPE1										
8	COPYBR INPUT TAPE1										
9	RETURN INPUT										
10	REWALLX										
11	COPYWER TAPE1 INPUT										
12	REWIND INPUT										
13	RFL 70000										
14	MNF, I=GASPAC, E=4, X										
15	(7/8/9 multipunch in column one) [master and demand decks]										
16	(7/8/9 multipunch in column one) [problem and blank cards]										
17	(6/7/8/9 multipunch in column one)										

†The text on each control card should be punched in the columns as shown. Parentheses indicate that the user should follow the punch instructions indicated or must insert user-supplied information. Brackets refer to a deck of computer cards that should be keypunched according to the format guide of Table 4.3.



# Chapter 5

## A Manual for Users of Mapping Programs

This chapter describes the application of computer mapping to emergency medical service planning. A map can be used to illustrate information on the relative importance of areas in a city. For example, a map of population concentration or total calls in city zones portrays geographical demand distributions in ways that tables or graphs cannot match. Mapping can illustrate policy alternatives and their implications, such as a set of proposed EMS sites and how they affect potential users. Prior to a discussion of the role of mapping in location analysis, a brief discussion of mapping is necessary. Rather than restate the contents of existing descriptions of mapping programs (see references [1], [2], and [3]), the chapter will refer to these sources.

Project members have primarily used two computer mapping programs called SYMAP (4) and SYMVU (5). A user can generate three types of maps with these programs: contour, proximal, and conformant maps. Conformant maps graph a region as a collection of bounded areas; they are appropriate for illustrating Austin's 358 serial zones. SYMAP maps are two-dimensional maps generated on a line printer. SYMVU maps are three-dimensional illustrations produced by a pen plotter. The relative importance of zones is denoted by symbols and altitudes on SYMAP and SYMVU maps, respectively.

### OVERVIEW

Conformant maps show bounded geographical areas within a larger study area and are useful when the area is divided into regions such as political districts or census tracts. Creating a conformant map requires three types of information:

- a source map or a set of bounded geographical areas described so as to be read by the SYMAP program;
- relative weights of regions, described as data corresponding to each bounded area; and
- map format instructions or directions for constructing a map.

In SYMAP these requirements are separated into three user-selected "packages." The source map or study area is described in the A-CONFORMOLINES package. Relative weights and the map format instructions are included in the E-VALUES and F-MAP packages, respectively. A package of job control commands call the SYMAP software for use. Although the form and placement of the job control commands vary from one system to another, the general arrangement of the user-selected packages is shown in Figure

5.1. The control commands necessary to operate SYMAP on The University of Texas at Austin computer system are listed in Table 5.5 of the Appendix.

The SYMAP output can include:

- a relisting of the A-CONFORMOLINES and E-VALUES packages;
- statistics on the zone weights and information on the map dimensions;
- a list of the zones and the corresponding weights;
- a conformant map with a key to symbolism; and
- a histogram of zone weight frequencies.

To be discussed later is the method by which it is possible to suppress the histogram, the relisting of the A-CONFORMOLINES package, or the relisting of the E-VALUES package. A sample of the output is included in Tables 5.12 through 5.15 of the Appendix.

In SYMVU the three types of information are separated into two user packages. The source map and the relative weights of each bounded area are combined in one package. These data are read as the weight of each point on an (x,y) coordinate system, called the "Data Matrix" (6). The SYMVU program also allows a user to access the SYMAP source map and relative weight information. If the SYMAP job control commands are modified and an instruction is included in the F-MAP package, the computer stores the SYMAP source map and data values for use in SYMVU. The OPTION package provides the user with a set of SYMVU electives for the production of the map. The output for SYMVU includes a three-dimensional illustration and a repeat of the instructions used in the OPTION package specifying the dimensions and angles for viewing the map.\*

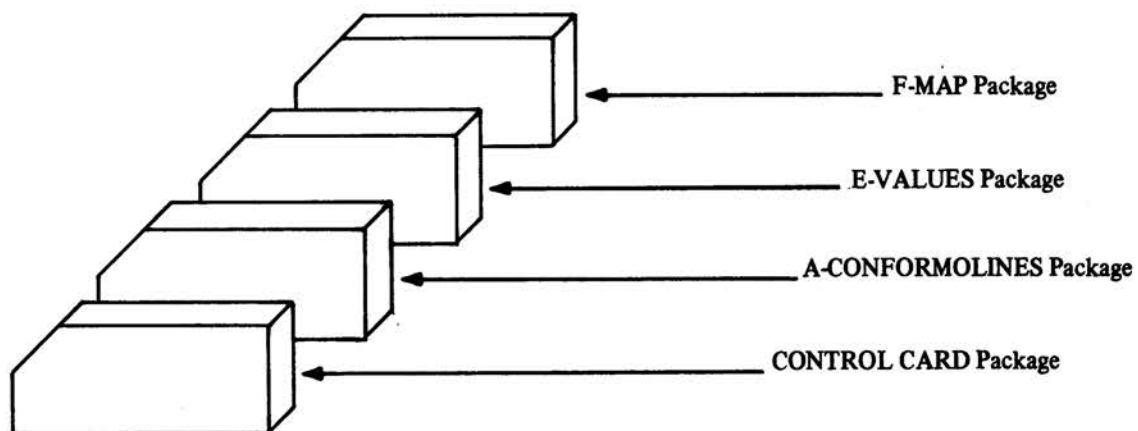
Figure 5.2 is a diagram of the relationship between SYMAP and SYMVU programs when the Data Matrix is read from a SYMAP-created tape. It shows how SYMVU can utilize the A-CONFORMOLINES and E-VALUES information and yet ignore SYMAP F-MAP map format instructions.

By storing the SYMAP-created Data Matrix, the user can easily generate multiple SYMVU three-dimensional maps. Different maps with various heights and viewing angles can be generated without having to recreate the Data Matrix

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\*The term "OPTION" is not used by the SYMVU authors but is used here to refer to the package of SYMVU commands in a way that is comparable to the SYMAP F-MAP package.

**Figure 5.1**  
**SYMAP Conformant Map Packages**



**Figure 5.2**  
**Relationship between SYMAP and SYMVU**

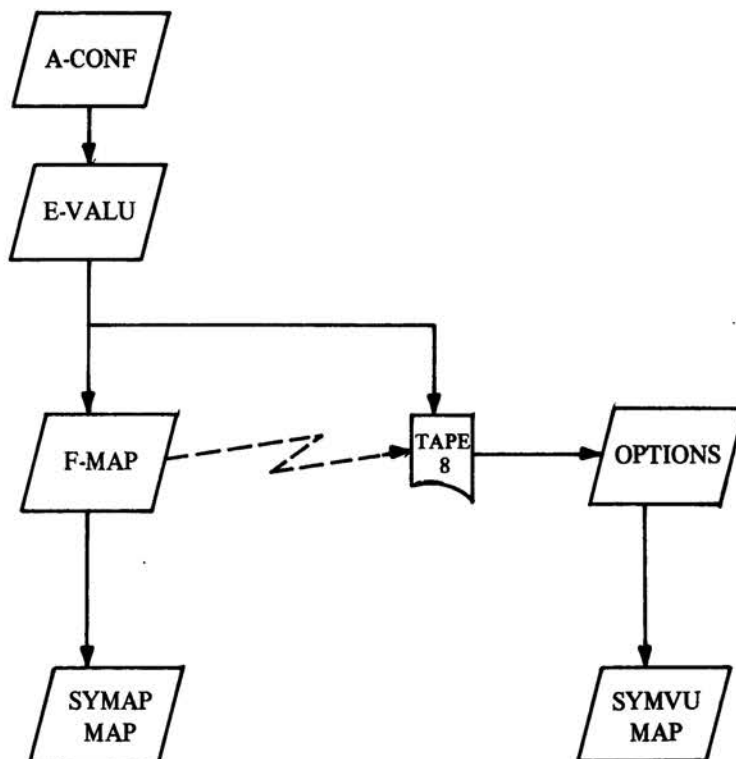
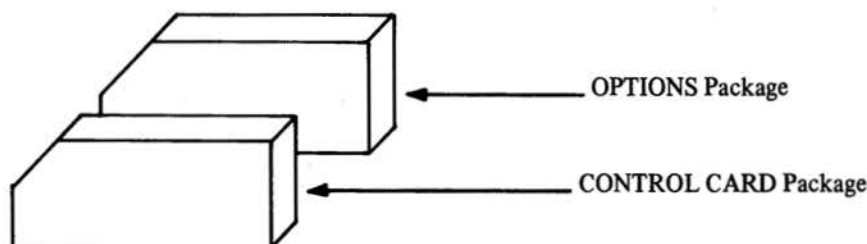


Figure 5.3  
SYMVU Conformant Map Packages



each time with SYMAP. If a stored SYMAP-created Data Matrix is used, each SYMVU job requires the two packages shown in Figure 5.3. Table 5.6 of the Appendix lists the job control cards used at The University of Texas at Austin.

If the user only wants a single SYMVU map, it is possible to add SYMVU options after the SYMAP F-MAP package, so as to produce both a SYMAP two-dimensional map and a SYMVU three-dimensional map at once. These changes are shown in Table 5.7 of the Appendix.

Although both two- and three-dimensional conformant maps show discrete zones, SYMAP and SYMVU display information differently. Two-dimensional maps use symbols to denote relative weights; data must be grouped and each group (usually a range of values or an interval) is represented by a symbol. Three-dimensional maps show relative weights through the map's third dimension, altitude. A unique altitude exists for each value—there is no need to group the data into intervals. These differences are reflected in the information and commands used to execute the two programs.

#### SYMAP AND SYMVU PACKAGES

Each SYMAP user package is identified by its name. The computer reads each package identifier to signal what is to come next. The end of each package is identified by a code consisting of five nines: "99999." Following the last package is an additional identifier of six nines: "999999." In SYMVU the OPTION package consists simply of three lines of commands. If SYMVU is not using a SYMAP-created data matrix, additional commands are necessary to enable SYMVU to read the data matrix from cards or from another tape source. A description of each package follows.

#### A-CONFORMOLINES

The A-CONFORMOLINES package is a set of statements

that describe the outlines of each geographical zone on the source map. Each zone is numbered and represented by a list of (x,y) coordinates. The A-CONFORMOLINES package consists of the set of ordered zone outlines and statements listing the boundary points of the entire source map. Additional information on the package is available in references (7) and (8). Table 5.9 in the Appendix lists specifications for keypunching the A-CONFORMOLINES package.

#### E-VALUES

The E-VALUES package provides weights corresponding to each zone as ordered on the source map. The number of values in this package must equal the number of zones. The package begins with the package identifier. Zonal weights are specified on successive cards, one zone to a card, beginning with zone one. Specifications for keypunching the E-VALUES package are given in Table 5.10 of the Appendix.

#### F-MAP and OPTIONS

The F-MAP package in SYMAP provides the computer with a set of user-selected electives for map construction. These electives determine how the two-dimensional conformant map will appear. The package includes three cards to be used for a map title, instructions on the number of intervals for grouping the data, the symbols to be employed, and the size of the map. Table 5.3 in the Appendix lists some SYMAP F-MAP electives and associated keypunch instructions. The electives shown in Table 5.3 are only the electives applicable to conformant maps and not a complete listing of the electives available to SYMAP users (9).

The OPTIONS package in SYMVU allows the user to determine the appearance of the three-dimensional conformant map. Selected electives for the OPTIONS package are given in Table 5.4 with keypunch instructions. A complete discussion of all SYMVU electives is available in the

SYMVU manual (10).

It is possible to suppress certain output from SYMAP. The listing of the A-CONFORMOLINES and E-VALUES packages is often unnecessary and easily avoided by inserting any character in columns 21 through 25 of the card used to identify the A-CONFORMOLINES or E-VALUES packages. The histogram, a table identifying the number of items in each interval, can involve several pages of output. The suppression of the histogram is accomplished by including elective 9 in the F-MAP package (see Table 5.3 of the Appendix).

### EMS PROJECT APPLICATION

The Austin EMS project members used conformant maps to illustrate the demographic conditions and EMS call patterns because these data were available for each of 358 transportation serial zones defined by the City of Austin Transportation Study Office (11). These zones correspond to the possible sites for EMS vehicle bases. Project members completed an A-CONFORMOLINES package in January 1978 describing the city of Austin and surrounding areas of Travis County (12). Various sets of data were used as E-VALUES to generate both two- and three-dimensional conformant maps. These sets are listed in Table 5.17 of the Appendix with index numbers for reference. The selection of

the electives in the F-MAP and OPTIONS packages varied with the nature of the information to be illustrated. All maps were kept to the same dimensions.

### SAMPLE CONFORMANT MAPS

#### SYMAP

In the Austin EMS study and in the sample maps that follow, the A-CONFORMOLINES package was read as needed from a stored permanent computer file. This system is advisable when many maps are to be produced using a complicated base map. The weights used for the E-VALUES package in the sample problem represent the total number of calls in a five-month period of 1976-1977. This package was always read by the computer using the card reader.

SYMAP conformant maps can be generated using only default values for each elective available in the F-MAP package. However, certain electives are necessary for some computer systems and other electives are advisable because of the nature of the information to be mapped. For the sample map showing total EMS calls, project members used a variety of electives. For illustrative purposes, the sample map employs many of the available electives (see Table 5.1). Table 5.11 of the Appendix lists all the cards (including the F-map package) used for the sample map.

Table 5.1  
List of Electives Used in Sample Problem

<i>Elective</i>	<i>Description</i>	<i>Value</i>
3	number of value class intervals	4.0
4	minimum weight value	-0.5
5	maximum weight value	69.0
6	length of first interval	1.0
	length of second interval	23.0
	length of third interval	23.0
	length of fourth interval	23.0
7	symbol for first interval	(blank)
	symbol for second interval	.
	symbol for third interval	+
	symbol for fourth interval	X
	symbol for lower than minimum	(blank)
	symbol for higher than maximum	■
	symbol for background	■
8	suppression of zone lines	
10	text: "Zones with no calls are shown as blank"	
15	number of vertical lines per inch	6.0
21	map stored on tape 8 for use with SYMVU	

Following the initial package identifier, "F-MAP," three title cards are required. These three cards can include any user comments. A common error is to use only one card; the computer then interprets the following two elective cards as part of the map title.

Electives 21 and 15 were essential for maps produced by project members. Elective 21 instructs the computer to store the SYMAP conformant map on tape for use in generating a SYMVU conformant map. Elective 15 specifies the number of vertical lines per inch and the number of horizontal characters per inch on the line printer being used. The line printer used by the project members printed six vertical lines per inch and ten characters per horizontal inch. It was only necessary to specify the six lines per vertical inch in Elective 15 since the horizontal default value is ten characters per inch. Omission of Elective 15 would result in a distorted map, elongated along the north-south direction.

The nature of the information being mapped determines the use of other electives; however, Elective 8 is necessary for mapping serial zones in Austin. This elective, when used, suppresses the zone lines which are shown as blank spaces between the zones. The zones in the central part of the city are so small that their inclusion leaves no room for weight symbols and the central city appears as a large blank area.

The use of electives 3, 4, 5, and 6, which relate to data intervals, depends on the information to be mapped. If these electives are omitted, the default is a set of five equally sized intervals, spanning the minimum and maximum weights contained in the E-VALUES package. Many of the project maps were generated with these default values. To illustrate a case of non-equal intervals the sample map uses four intervals. The minimum value was specified as -0.5 by using Elective 4 and the maximum was specified as 69.0 by using Elective 5. The four intervals between these two extremes were not divided equally but have ranges of -0.5 to 0.5; 0.5 to 23.5; 23.5 to 46.5; and 46.5 to 69.5, respectively. This grouping shows zones with zero calls separately. If values lower than the specified minimum or higher than the specified maximum are encountered in the E-VALUES package, the corresponding zone will be covered by the symbols "L" or "H" respectively (unless specified otherwise by Elective 7).

Elective 7 permits the user to select the symbols used in mapping. If Elective 7 is not used, the symbols will be the standard set shown in Table 5.16 of the Appendix. The sample map illustrates the use of user-selected symbols. The use of blanks to indicate a zone with zero calls resulted in a conformant map that was not clearly defined along the outside boundaries where most zones with zero calls exist. It was therefore necessary to create a background using the symbol "■" (OXAV overprint).

Elective 10 provides additional space to include text. In the sample map this space was used to add the text: "Zones

with no calls are shown as blank."

Figure 5.4 shows the completed map; other types of output information are included in Tables 5.12 through 5.15 of the Appendix. To illustrate how SYMAP handles zone weights outside the specified minimum-to-maximum range, the maximum weight was intentionally specified lower than 73 (the actual maximum value in the E-VALUES package), thus forcing the sample map to use the symbol "■" (OXAV overprint) as specified in Elective 7 to show these zones.

## SYMVU

The SYMVU OPTIONS package consists of a title card and two elective cards. The second and third cards include space for electives 2-1 and 2-22 and 3-1 to 3-10, respectively. Table 5.4 of the Appendix lists selected electives which were used by project members in the Austin EMS study. Not all available electives are necessary to produce a three-dimensional conformant map. In fact, if a SYMAP-created data matrix is used as input, only three SYMVU electives (2-4, 2-12, and 2-18) are necessary to generate a map. The SYMVU manual also indicates that electives 2-1 and 2-2, which specify the dimensions of the data matrix, must be used (13). However, a programmer analyst at The University of Texas at Austin, David Carver, has implemented the SYMAP and SYMVU programs such that these electives are not necessary on the University computer.

Elective 2-4 specifies the direction along which lines are to be drawn. Depending on the angle chosen for viewing the map as specified in Elective 3-2 (azimuth), the direction of the lines can be north to south, east to west, or along diagonals. The preferred direction for each azimuth value specified in Elective 3-2 is given in the SYMVU manual (14). Project members found that maps look best if lines appear along the east-west direction or along the "rows."

Elective 2-12 specifies the number of vertical lines per inch for the SYMAP maps when SYMAP-created files are used as the data matrix for SYMVU. The value in this elective must agree with the value in Elective 21 of the SYMAP F-MAP package. For the sample map this value was 6.

Elective 2-18 tells the computer to read the weights for each of the (x,y) coordinates of the data matrix from a SYMAP-created file. These electives and others used in the sample map are shown in Table 5.2. The map which was generated is shown in Figure 5.5. The entire job which produced this sample map is shown in Table 5.11 of the Appendix.

## CONSIDERATIONS IN MAP PRODUCTION

### SYMAP

The use of transportation serial zones for the division of



Figure 5.4

## Sample SYMAP Conformant Map of Total Call History



**Table 5.2**  
**Options Used in Sample Problem**

<i>Option</i>	<i>Description</i>	<i>Value</i>
2- 4	lines along rows	2
2- 8	crosshatch on base	2
2-12	number of vertical lines per inch used in SYMAP input	6
2-16	block base	3
2-18	weights from SYMAP input	1
3- 1	map viewed at 35 degrees above horizon	35.00
3- 2	top of map turned 15 degrees east of north	15.00
3- 3	width of map is 6 inches	6.00
3- 4	height of map is 3 inches	3.00

**Figure 5.5**  
**Sample SYMVU Conformant Map of Total Call History**  
(from a perspective of 35 degrees)

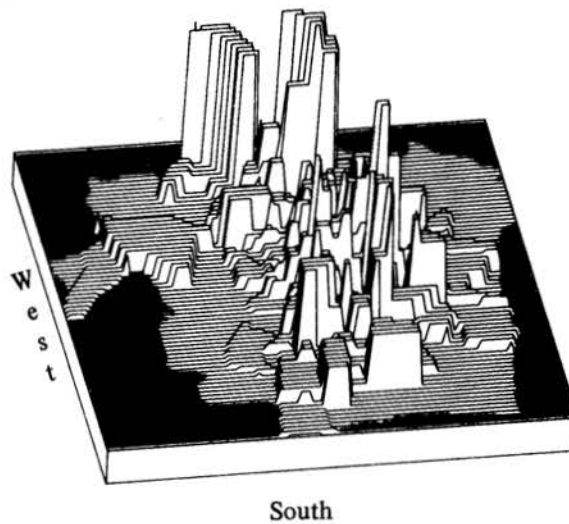


Figure 5.6  
Use of Centroids to Show Total Call History



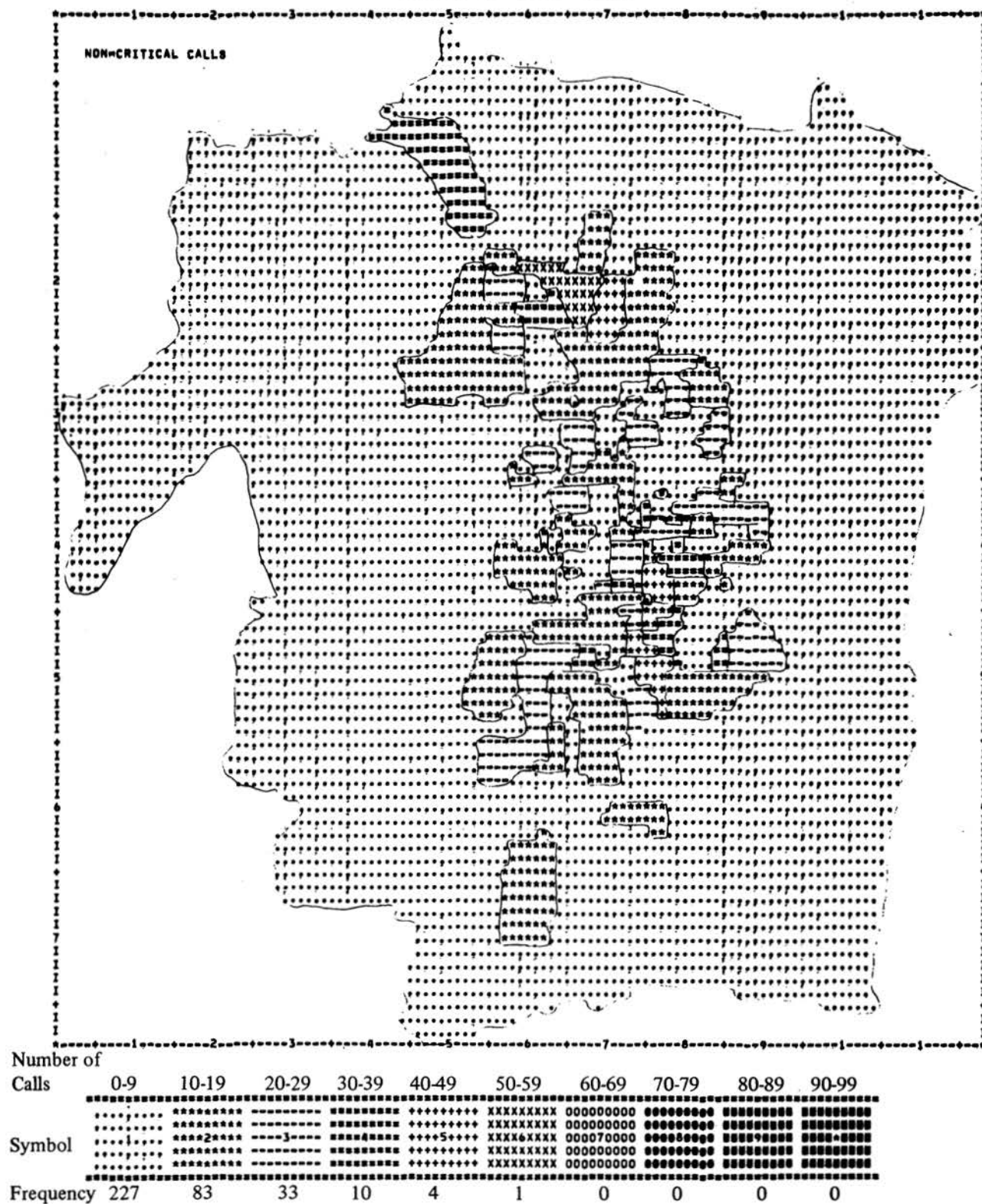


Figure 5.7

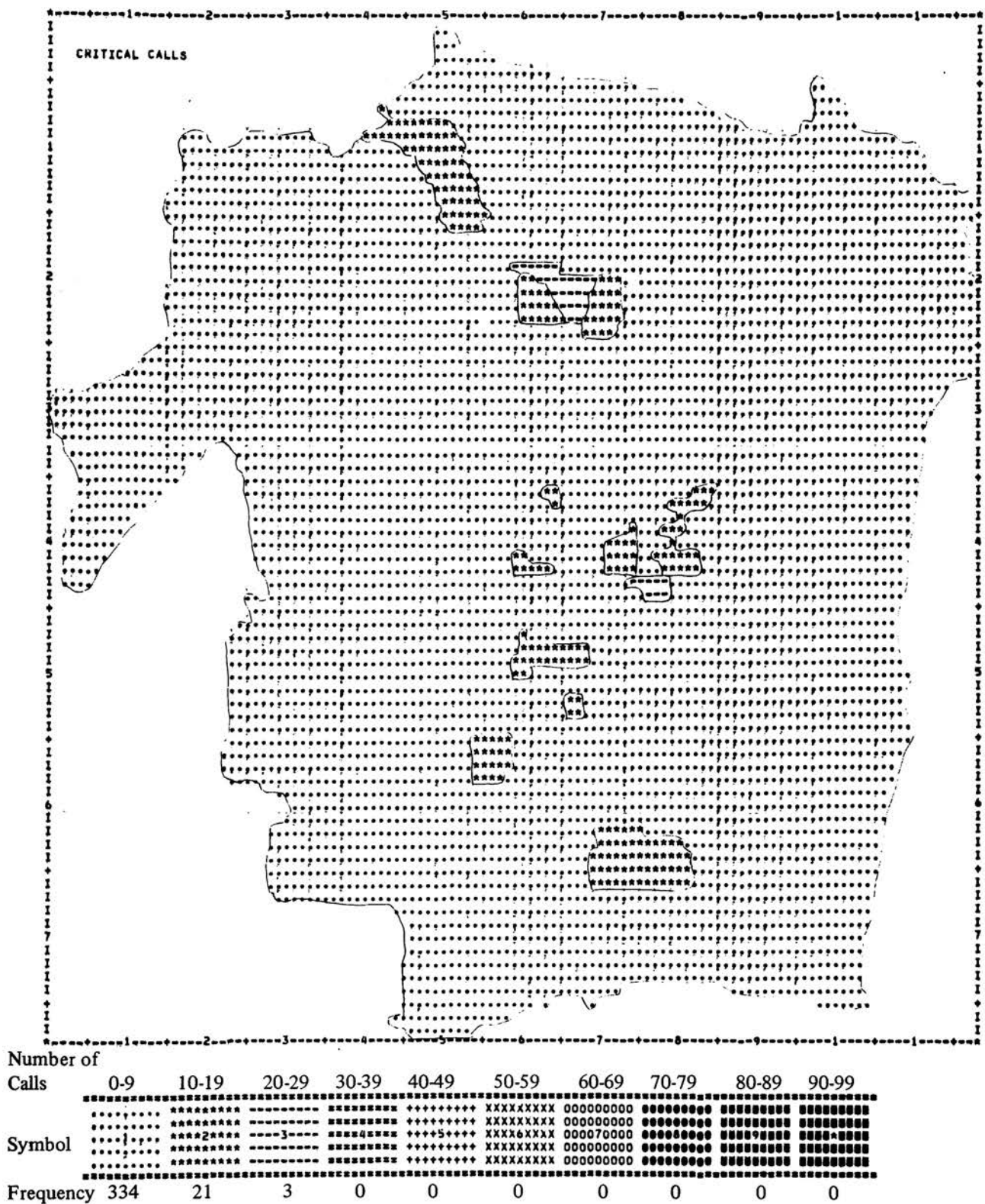
## SYMAP Map of Calls per Person



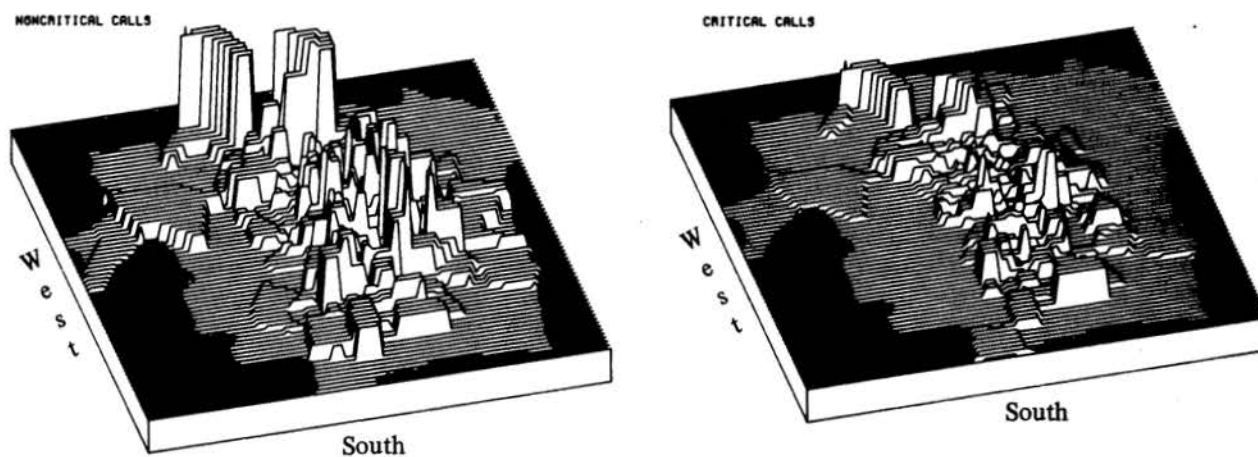
Figure 5.8  
Comparison of SYMAP Maps Showing Critical and Noncritical Calls  
Using Standardized Intervals



**Figure 5.8 (continued)**



**Figure 5.9**  
**Comparison of SYMVU Maps Showing Critical and Noncritical**  
**Calls Using Standardized Height**  
 (from a perspective of 35 degrees)



the study area may distort some information because zones vary in size. A large zone with a large value will seem more impressive than a small zone with the same value, as the entire area of the zone is covered by the same symbol.

One way to illustrate zones with the largest number of calls is to use a symbol as the centroid of each zone.\* Compare Figure 5.6 with Figure 5.4, as each shows the total number of calls in each zone. In Figure 5.4 the larger zones close to the map's borders obscure the fact that most calls occur closer to the city's center.

It is possible to map other related data. For example, the number of calls per person could be mapped by using a set of weights derived by dividing total calls in a zone by the population of that zone (see Figure 5.7). Different job control commands and a short data manipulation program were used to produce this map; the changed job control cards and the FORTRAN program are shown in Table 5.8 of the Appendix.

Care must be taken in making comparisons between different maps employing different variables with different

ranges and intervals. Comparisons are more appropriate for maps with a standard interval and symbol set. The two maps in Figure 5.8 compare critical calls and noncritical calls using the same ten equal intervals between 0 and 100.

## SYMVU

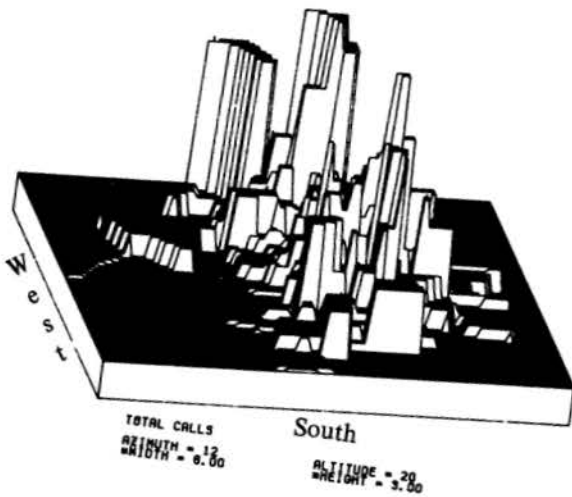
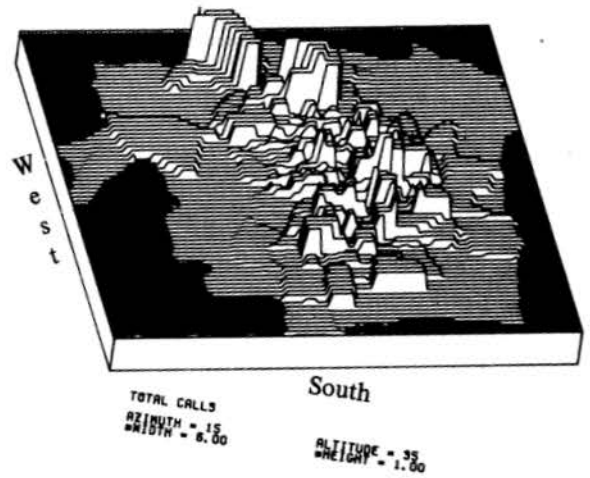
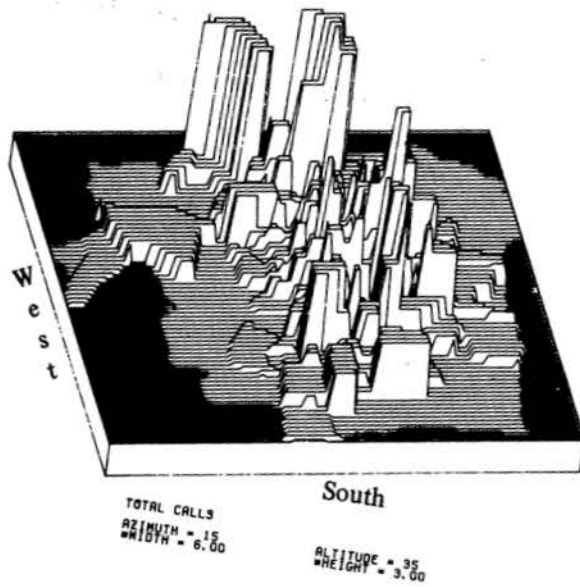
Comparisons between SYMVU conformant maps is also difficult because each map has a unique upper and lower bound. A standard measure of height can be used to correct for these differences so that each map will have a different height. As an example, noncritical and critical calls are shown in Figure 5.9. The height standard for both maps is 100 calls equals 4 inches (note that the maps have been reduced in the attached reproductions).

The choice of altitude and height can also affect the appearance of SYMVU conformant maps. High peaks obscure low valleys and make it difficult to associate the weights with zones on the map. Altering the viewing angle or altitude specified in Elective 3-1 of the OPTION package can improve the view. However, simply decreasing the height in Elective 3-4 reduces the variation and also makes viewing easier. Figure 5.10 illustrates these effects through four maps with different viewing angles and/or heights.

\*Centroid maps require the use of the B-DATA POINTS package which is not discussed here. For information on the B-DATA POINTS package see the *SYMVU Manual*.



Figure 5.10  
Comparison of SYMVU Maps  
with Different Heights and/or Altitudes



## REFERENCES

- (1) Laboratory for Computer Graphics and Spatial Analysis (LCGSA), *SYMAP User's Reference Manual*, fifth edition (Cambridge, Massachusetts: Graduate School of Design, Harvard University, September 1975).
- (2) LCGSA, *SYMVU Manual*, third edition (Cambridge, Massachusetts: Graduate School of Design, Harvard University, July 1977).
- (3) Emergency Medical Services Policy Research Project, *Location Techniques for Emergency Medical Services Vehicles, Volume I: An Analytical Framework for Austin, Texas* (Austin, Texas: LBJ School of Public Affairs, The University of Texas at Austin, 1979).
- (4) LCGSA, *SYMAP User's Reference Manual*.
- (5) LCGSA, *SYMVU Manual*.
- (6) Ibid.
- (7) LCGSA, *SYMAP User's Reference Manual*.
- (8) Emergency Medical Services Policy Research Project.
- (9) LCGSA, *SYMAP User's Reference Manual*.
- (10) LCGSA, *SYMVU Manual*.
- (11) Emergency Medical Services Policy Research Project.
- (12) Ibid.
- (13) LCGSA, *SYMVU Manual*.

## APPENDIX

Table 5.3 gives selected electives from the SYMAP F-MAP package. Only those electives applicable to conformant maps are included. Table 5.4 gives selected electives from the SYMVU OPTIONS package. Only those electives which were found necessary for the maps produced by project members in the Austin EMS study have been included in the table.

Tables 5.5, 5.6, 5.7, and 5.8 give the control commands necessary to run SYMAP and SYMVU. Table 5.5 lists the commands for a SYMAP conformant map of the city of Austin. Table 5.6 lists the commands for storing the SYMAP-created data matrix in a permanent computer file for use with SYMVU at a later time. Table 5.7 lists the commands for generating SYMAP and SYMVU conformant maps at once without storage of the data matrix. Table 5.8 gives the control commands and the program to produce a map with E-VALUE weights as a ratio of two sets of data.

Tables 5.9 and 5.10 provide keypunch instructions for the A-CONFORMOLINES package and the E-VALUES package, respectively.

Tables 5.11 through 5.15 are related to the sample problem discussed in the text. Table 5.11 is a list of the cards used to produce the map in Figure 5.4 with keypunch instructions. Table 5.12 shows a part of the A-CONFORMOLINES and E-VALUES listing that is included with the map output if not suppressed in the package identifier. Table 5.13 shows the statistics on the zone weights and the information on the map dimensions for the sample map. Table 5.14 shows part of the list of zones and the corresponding weights. Table 5.15 shows a part of the histogram for the sample map.

Table 5.16 shows the standard symbols used in the F-MAP package in SYMAP. Table 5.17 lists the weights used as E-VALUES in the Austin EMS study.

Table 5.3  
Selected SYMAP Electives

<i>Elective Number</i>	<i>Definition</i>	<i>Card Number</i>	<i>Column Number</i>	<i>Format*</i>	<i>Value</i>	<i>Explanation</i>	<i>Default</i>	<i>Comments</i>
1	map dimensions	1	5 11-20 21-30	I F F	1	identifies elective vertical dimension in inches horizontal dimension in inches	13 13	default will be 13 inches in width or in length, whichever is greater
3	number of value class intervals	1	5 11-20	I F	3 1.0-10.0	identifies elective number of intervals desired	5.0	must be an integer
4	value range minimum	1	5 11-20	I F	4	identifies elective desired minimum	E-Value minimum	can be negative
5	value range maximum	1	5 11-20	I F	5	identifies elective desired maximum	E-Value minimum	can be negative
6	ranges of value class intervals	1	5 11-20 21-30 31-40 41-50 51-60 61-70	I F F F F F F	6	identifies elective length of first interval length of second interval length of third interval length of fourth interval length of fifth interval length of sixth interval	intervals of equal length	
		2	21-30 31-40 41-50 51-60	F F F F		length of seventh interval length of eighth interval length of ninth interval length of tenth interval		
7	symbolism	1	5	I	7	identifies elective		
		2	11-20	A		symbols in zones for intervals 1-10	standard symbols	
			21	A		symbols at centroids for intervals 1-10	standard symbols	
			22	A		symbol for zones with weights less than minimum specified in Elective 5	L	
			23	A		symbol for centroids with weights less than minimum specified in Elective 5	L	
			24	A		symbol for zones with weights greater than maximum specified in Elective 5	H	
			25	A		symbol for centroids with weights greater than maximum specified in Elective 5	H	
			26	A		symbol for background	(blank)	
		3-5	1-26	A		symbol for zone boundary lines	(blank)	
						overprint of characters in columns 1- of other cards 2-5	(blank)	use of elective 8 will override any symbol in column 26
8	suppression of contour lines or boundaries	1 1	5 5	I	8	identifies elective	zone lines printed	no other variables required



Table 5.3 (continued)

<i>Elective Number</i>	<i>Definition</i>	<i>Card Number</i>	<i>Column Number</i>	<i>Format*</i>	<i>Value</i>	<i>Explanation</i>	<i>Default</i>	<i>Comments</i>
9	suppression of histogram	1	5	I	9	identifies elective	histogram printed	no other variables required
10	explanatory text	1	4-5	I	10	identifies elective	no text	all thirty cards not necessary
		2-31 (last)	1-72 1-4	A I	9999	characters of text, up to 30 cards indicates end of text		
15	number of characters per inch	1	4-5 11-20 21-30	I F F	15	identifies elective number of rows per inch number of columns per inch	8 rows/inch 10 columns/inch	
21	symvu tape	1	4-5	I	21	identifies elective	no tape	no other variables required

\* I = Integer right justified in field; F = Decimal number in field; A = Alphabetic or Numeric characters.

Source: Adapted from Elliot E. Dudnik, *SYMAP User's Reference Manual* (Chicago: Department of Architecture, University of Illinois at Chicago Circle, 1971).

**Table 5.4**  
**Selected SYMVU Electives**

<i>Elective Number</i>	<i>Definition</i>	<i>Column Number</i>	<i>Format*</i>	<i>Value</i>	<i>Explanation</i>	<i>Default</i>	<i>Comments</i>
2- 4	Linetype	16	I	1	lines along columns	no map produced	for azimuth 90-270 for azimuth 0-180 for any other angle
				2	lines along rows		
				4	lines along diagonals		
2- 8	Nozero	32	I	1	prints nothing on base		If using SYMAP as input 2-8 recommended to eliminate random pattern
				2	prints crosshatch on base		
				0	prints lines on base		
2-11	Endlin	44	I	1	deletes endlines	draws endlines	
2-12	Symap	45-48	I	0-10	specifies vertical lines per inch from SYMAP	8 lines per inch	
2-16	Base	60	I	1	deletes base	no base produced	
				2	draws a base following map boundaries		
				3	draws a block base		
2-18	F data	65-68	I	1	specifies input data from SYMAP tape	no map produced	no map unless data input by cards
3-1	Altitude	1- 5	F	0.00-360.00	elevation viewed above horizontal	0.00	
3- 2	Azimuth	6-10	F	0.00-360.00	number of degrees map is turned towards east	0.00	
3- 3	Width	11-15	F	0.00- 10.00	width of map in inches	6.00	
3- 4	Height	16-20	F	0.00- 10.00	height of map in inches	3.00	

\*I = Integer right justified in field; F = Decimal number in field; A = Alphabetic or Numeric characters.

Source: Adapted from Laboratory for Computer Graphics and Spatial Analysts Graduate School of Design, *SYMVU Manual*, (Cambridge, Mass.: Harvard University, 1977).

**Table 5.5**  
**SYMAP Control Cards at**  
**The University of Texas at Austin**

<i>Card Number</i>	<i>Column</i>	11111111112222222223 123456789012345678901234567890
1		(user number)
2		(password)
3		JOB,TM=50,PR=100
4		READPF,3473,AUSMAP
5		COPYBR,AUSMAP,TAPE1
6		COPYBR,INPUT,TAPE1
7		REWIND TAPE1
8		COPYWER,TAPE1,FILE1
9		REWIND FILE1
10		PUBLIC,SYMAP,FILE1
11		(7/8/9 multipunch) [E-VALUES package] [F-MAP package]
12		(6/7/8/9 multipunch)

The text of each card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the keypunch instructions. Brackets refer to a deck of computer cards.

**Table 5.6**  
**Modified SYMAP Control Cards for Creation of**  
**SYMVU Maps from Stored Data Matrix**

Modified SYMAP Control Cards

<i>Card Number</i>	<i>Column</i>	11111111112222222223 123456789012345678901234567890
1		(user number)
2		(password)
3		JOB,TM=50,PR=100
4		READPF,3473,AUSMAP
5		COPYBR,AUSMAP,TAPE1
6		COPYBR,INPUT,TAPE1
7		REWIND TAPE1
8		COPYWER,TAPE1,FILE1
9		REWIND FILE1
10		PUBLIC,SYMAP,FILE1
11		SAVEPF,B635,5004,TAPE8
12		(7/8/9 multipunch) [E-VALUES package] [F-MAP package]
13		(6/7/8/9 multipunch)

SYMVU Control Cards

1	(user number)
2	(password)
3	JOB,TM=50,PR=100
4	READPF,B635,TAPE8
5	PUBLIC,SYMVU,INPUT
6	DISPOSE,PLOTR/00
7	QUEUES,J
8	(7/8/9 multipunch) [OPTION package]
9	(6/7/8/9 multipunch)

The text of each card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the keypunch instructions. Brackets refer to a deck of computer cards.

Table 5.7

**Modified SYMAP Control Cards for Creation of SYMVU Maps**  
(no stored data matrix)

<i>Card Number</i>	<i>Column</i> 1      5      10      15      20      25      30
1	(user number)
2	(password)
3	JOB,TM=50,PR=100
4	READPF,3473,AUSMAP
5	COPYBR,AUSMAP,TAPE1
6	COPYBR,INPUT,TAPE1
7	REWIND TAPE1
8	COPYWER,TAPE1,FILE1
9	REWIND FILE1
10	PUBLIC,SYMAP,FILE1
11	REWIND TAPE8
12	PUBLIC,SYMVU,INPUT
13	DISPOSE,PLOTR/00
14	(7/8/9 multipunch) [E-VALUES package] [F-MAP package]
15	(7/8/9 multipunch) [OPTION package]
16	(6/7/8/9 multipunch)

The text of each card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the keypunch instructions. Brackets refer to a deck of computer cards.

**Table 5.8**  
**Control Cards and Program to Create a Map Using a Ratio of Zone Weights**

Card Number	Column	1	5	10	15	20	25	30	35	40		
1		(job number)										
2		(password)										
3		JOB TM=35,PR=100										
4		MNF.										
5		READPF,3473,AUSMAP										
6		COPYBR,AUSMAP,TAPE4										
7		COPYBR,INPUT,TAPE1										
8		COPYBR,INPUT,TAPE2										
9		COPYBR,INPUT,TAPE5										
10		REWALLX TAPE4										
11		LGO.										
12		REWIND TAPE3										
13		COPYBR,TAPE3,TAPE4										
14		COPYBR,TAPE5,TAPE4										
15		REWIND TAPE4										
16		COPYWER,TAPE4,FILE1										
17		REWIND FILE1										
18		PUBLIC SYMAP,FILE1										
19		SAVEPF,B635,5001,TAPE8										
20		(7/8/9 multipunch)										
21		PROGRAM VARPER(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3)										
22	20	FORMAT(12X,F8.0)										
23	30	FORMAT(12X,F8.5)										
24		WRITE(3,31)										
25		DO 10 I=1,358										
26		VPER=-1.0										
27		READ(1,20) VAR										
28		READ(2,20) POP										
29		IF(POP.EQ.0.0) GO TO 10										
30		VPER=VAR/POP										
31	10	WRITE(3,30) VPER										
32		WRITE(3,32)										
33	31	FORMAT(*E-VALUES							X*)			
34	32	FORMAT(*99999*)										
35		END										
36		(7/8/9 multipunch)										
		[E-VALUES package 1 = dividend or "VAR"]										
37		(7/8/9 multipunch)										
		[E-VALUES package 2 = divisor or "POP"]										
38		(7/8/9 multipunch)										
		[F-MAP package]										
39		(6/7/8/9 multipunch)										

The text of each card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the keypunch instructions. Brackets refer to a deck of computer cards.

**Table 5.9**  
**A-CONFORMOLINES Key punch Instructions**

<i>Card</i>	<i>Column(s)</i>	<i>Format</i>	<i>Variable</i>	<i>Description</i>
First card of package	1-15	A	A-CONFORMOLINES	identifies package
	12-25	A	(any character)	suppresses printed listing of A-Conformolines with max output
Last card of package	1- 5	I	99999	identifies end of package
First card of each conformant outline	1- 5	I	(zone reference number for conformant outline)	reference for the corresponding E-Value weights
	10	A	A	identifies conformant outline as an area
			L	identifies conformant outline as a line
			P	identifies conformant outline as a point
	11-20	F	X	X coordinate measured down from top
Succeeding cards of each conformant outline	21-30	F	Y	Y coordinate measured across from left
	11-20	F	X	X coordinate measured down from top
	21-30	F	Y	Y coordinate measured across from left

Source: Adapted from Elliot E. Dudnik, *SYMAP User's Reference Manual* (Chicago: Department of Architecture, University of Illinois at Chicago Circle, 1971).

**Table 5.10**  
**E-VALUES Keypunch Instructions**

<i>Card</i>	<i>Column(s)</i>	<i>Format*</i>	<i>Variable</i>	<i>Description</i>
First Card	1- 8	A	E-VALUES	identifies package
	21-25	A	(any nonblank character)	supplies printed listing of E-Value weights with max output
Last card of package	1- 5	I	99999	identifies end of package
Other cards (arranged in numerical order according to the zone reference number)	11-20	F	weight	weight associated with ?th zone on ?th card
	73-80	A	(any character)	for user reference—zone reference numbers advised

\*I=Integer right justified in field; F=Decimal number in field; A=Alphabetic or Numeric characters.

Source: Adapted from Laboratory for Computer Graphics and Spatial Analysts Graduate School of Design, *SYMVU Manual*, (Cambridge, Mass.: Harvard University, 1977).



**Table 5.11**  
**Cards for Creation of Sample SYMAP Maps**

Card Number	Columns						
	1	5	10	15	20	25	30
1	(user number)						
2	(password)						
3	JOB, TM=50, PR=100						
4	READPF, 3473, AUSMAP						
5	COPYBR, AUSMAP, TAPE1						
6	COPYBR, INPUT, TAPE1						
7	REWIND TAPE1						
8	COPYWER, TAPE1, FILE1						
9	REWIND FILE1						
10	PUBLIC, SYMAP, FILE1						
11	SAVEPF, B635, 5004, TAPE8						
12	(7/8/9 multipunch)						
13-372	[E-VALUES package]						
373	F-MAP						
374	TOTAL CALL HISTORY						
375	(blank)						
376	(blank)						
377		3	4.0				
378		4	-0.5				
379		5	69.0				
380		6	1.0		23.0	23.0	23.0
381		7					
382		.+x					
383					O O		
384					X X		
385					A A		
					V V		
386		8					
387		10					
388	ZONES WITH NO CALLS ARE SHOWN AS BLANK						
389	9999						
390		15	6.0				
391		21					
392	99999						
393	999999						
394	(6/7/8/9 multipunch)						
SYMVU Cards							
1	(user number)						
2	(password)						
3	JOB, TM=50, PR=100						
4	READPF, B635, TAPE8						
5	PUBLIC, SYMVU, INPUT						
6	DISPOSE, PLOTR/00						
7	QUEUES, J						
8	(7/8/9 multipunch)						
9	TOTAL CALL HISTORY						
10		2			2	6	3
11		15.00	12.00	6.00	3.00		1
12	(6/7/8/9 multipunch)						

The text of each card should begin in the first column. The use of parentheses, brackets, and lower case letters indicate that the text should not be punched as shown. Parentheses indicate that the user should follow the keypunch instructions. Brackets refer to a deck of computer cards.

Table 5.12

Sample A-CONFORMOLINES and E-VALUES  
Packages from SYMAP Output

A=CONFORMOLINES *****			E=VALUES *****	
VERTEX	DOWN	ACROSS	DATUM	VALUE
349 AREA				
( 1)	.50	9.60	( 1)	4.00
( 2)	.80	9.70	( 2)	26.00
( 3)	1.30	9.60	( 3)	3.00
( 4)	2.20	9.50	( 4)	3.00
( 5)	2.00	9.70	( 5)	8.00
( 6)	2.60	8.00	( 6)	12.00
( 7)	1.40	9.40	( 7)	12.00
( 8)	.90	9.30	( 8)	20.00
( 9)	.00	9.30	( 9)	6.00
( 10)	.50	9.60	( 10)	5.00
LENGTH=	6.95		( 11)	2.00
AREA=	1.43		( 12)	8.00
CENTER=(	2.02,	9.12)	( 13)	9.00
350 AREA			( 14)	9.00
( 1)	.80	9.70	( 15)	2.00
( 2)	1.10	9.90	( 16)	35.00
( 3)	1.30	10.20	( 17)	10.00
( 4)	1.50	11.20	( 18)	3.00
( 5)	2.30	11.30	( 19)	12.00
( 6)	3.00	11.30	( 20)	3.00
( 7)	2.00	9.70	( 21)	8.00
( 8)	2.20	9.50	( 22)	8.00
( 9)	1.30	9.60	( 23)	16.00
( 10)	.00	9.70	( 24)	23.00
LENGTH=	6.91		( 25)	14.00
AREA=	2.72		( 26)	7.00
CENTER=(	2.09,	10.39)	( 27)	12.00
351 AREA			( 28)	16.00
( 1)	1.50	11.20	( 29)	9.00
( 2)	1.50	11.90	( 30)	6.00
( 3)	1.00	12.20	( 31)	0.00
( 4)	1.90	13.00	( 32)	7.00
( 5)	3.30	13.40	( 33)	4.00
( 6)	3.20	13.10	( 34)	6.00
( 7)	3.10	12.30	( 35)	0.00
( 8)	3.00	11.60	( 36)	4.00
( 9)	3.00	11.30	( 37)	10.00
( 10)	2.30	11.30	( 38)	7.00
( 11)	1.50	11.20	( 39)	12.00
LENGTH=	7.02		( 40)	6.00
AREA=	2.66		( 41)	10.00
CENTER=(	2.41,	12.20)	( 42)	6.00
			( 43)	3.00
			( 44)	8.00
			( 45)	10.00
			( 46)	7.00
			( 47)	15.00
			( 48)	19.00
			( 49)	0.00
			( 50)	10.00
			( 51)	17.00
			( 52)	3.00

Table 5.13

Sample SYMAP Output  
Zone Weight Statistics and Map Dimension Information

```

MAP WINDOW DISPLAYED IS
      (      .500,      .500) (TOP=LEFT CORNER)
      ( 24.100, 21.922) (BOTTOM=RIGHT CORNER)

MAP SCALE =      .5500 (INCHES ON OUTPUT MAP)/(UNITS ON SOURCE MAP)

MAP SHOULD BE PRINTED AT  6.0 ROWS PER INCH AND 10.0 COLUMNS PER INCH

TRANSFORMATION FROM SOURCE COORDINATES TO PRINT CHARACTER LOCATION IS
ROW      = (DOWN  COORDINATE =      .50) *      3.3051
COLUMN   = (ACROSS COORDINATE =      .50) *      5.5005

THERE ARE 356 VALID DATA VALUES

MINIMUM AND MAXIMUM VALID DATA VALUES ARE      0.000 AND      73.000

MEAN OF VALID DATA IS      12.081

STANDARD DEVIATION OF VALID DATA IS      12.654

```

Table 5.14

Sample SYMAP Output  
List of Zones and Corresponding Weights

## CONFORMOLINES FOR MAP

ZONE	TYPE	ROW	COLUMN	DATUM	VALUE	LEVEL
349)	A	5	47	349	0.00	1
350)	A	5	54	350	0.00	1
351)	A	6	64	351	0.00	1
352)	A	8	76	352	0.00	1
353)	A	10	88	353	0.00	1
354)	A	11	103	354	0.00	1
356)	A	14	117	356	0.00	1
357)	A	16	114	357	0.00	1
291)	A	20	113	291	0.00	1
293)	A	16	105	293	0.00	1
358)	A	19	106	358	0.00	1
355)	A	16	100	355	0.00	1
317)	A	19	99	317	0.00	1
294)	A	16	94	294	0.00	1
295)	A	14	88	295	0.00	1
296)	A	14	82	296	1.00	1
160)	A	12	77	160	4.00	1
126)	A	12	72	126	4.00	1
299)	A	9	67	299	1.00	1
297)	A	9	62	297	0.00	1
125)	A	12	67	125	1.00	1
298)	A	12	61	298	0.00	1
270)	A	10	55	270	5.00	1
269)	A	11	49	269	53.00	4

**Table 5.15**  
**Sample SYMAP Output**  
**Histogram**

DATA VALUE EXTREMES ARE 0.00 73.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL  
(\*MAXIMUM\* INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.00	14.60	29.20	43.80	58.40
MAXIMUM	14.60	29.20	43.80	58.40	73.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

20.00 20.00 20.00 20.00 20.00

**FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL**

[illegible]

FREQ.	245	76	25	9	3
1	1.,1.,1	1+2+1	1003001	1004001	1005001
2	1.,1.,1	1+2+1	1003001	1004001	1005001
3	1.,1.,1	1+2+1	1003001	1004001	1005001
4	1.,1.,1	1+2+1	1003001	1004001	
5	1.,1.,1	1+2+1	1003001	1004001	
6	1.,1.,1	1+2+1	1003001	1004001	
7	1.,1.,1	1+2+1	1003001	1004001	
8	1.,1.,1	1+2+1	1003001	1004001	
9	1.,1.,1	1+2+1	1003001	1004001	
10	1.,1.,1	1+2+1	1003001		
11	1.,1.,1	1+2+1	1003001		
12	1.,1.,1	1+2+1	1003001		
13	1.,1.,1	1+2+1	1003001		
14	1.,1.,1	1+2+1	1003001		
15	1.,1.,1	1+2+1	1003001		
16	1.,1.,1	1+2+1	1003001		
17	1.,1.,1	1+2+1	1003001		
18	1.,1.,1	1+2+1	1003001		
19	1.,1.,1	1+2+1	1003001		
20	1.,1.,1	1+2+1	1003001		
21	1.,1.,1	1+2+1	1003001		
22	1.,1.,1	1+2+1	1003001		
23	1.,1.,1	1+2+1	1003001		
24	1.,1.,1	1+2+1	1003001		
25	1.,1.,1	1+2+1	1003001		
26	1.,1.,1	1+2+1			
27	1.,1.,1	1+2+1			
28	1.,1.,1	1+2+1			
29	1.,1.,1	1+2+1			
30	1.,1.,1	1+2+1			
31	1.,1.,1	1+2+1			
32	1.,1.,1	1+2+1			
33	1.,1.,1	1+2+1			
34	1.,1.,1	1+2+1			
35	1.,1.,1	1+2+1			
36	1.,1.,1	1+2+1			

**Table 5.16**  
**Standard Symbolism Used by SYMAP**

*Number of intervals specified*

*Standard symbolism for intervals*

10  
9  
8  
7  
6  
5  
4  
3  
2  
1

1 2 3 4 5 6 7 8 9 10

. , - = + X O Θ ▣ ▤  
. , = + X O Θ ▣ ▤  
. , + X O Θ ▣ ▤  
. , + X Θ ▣ ▤  
. + X Θ ▣ ▤  
. + O Θ ▤  
. + O ▤  
. O ▤  
. ▤  
.

▣ = OXAV overprint

Source: Elliot E. Dudnik, *SYMAP User's Reference Manual* (Chicago: Department of Architecture, University of Illinois at Chicago Circle, 1971).

**Table 5.17**  
**E-VALUE Weights Used in EMS Study**

<i>Index Number</i>	<i>Title</i>
001	total number of calls
002	white population
003	black population
004	stroke incidents
005	baby, house, unconscious, unknown incidents
006	minority population
007	drug incidents
008	gunshot incidents
009	auto incidents
	Calls responded to by:
010	ambulance one
011	ambulance two
012	ambulance three
013	ambulance four
014	ambulance five
015	ambulance six
016	ambulance seven
017	critical calls
018	noncritical calls
019	transport calls
020	nontransport calls
021	unconscious incidents
022	baby, house, unknown incidents
023	Spanish population
024	time to nearest station
025	population over 62



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*Volume I: An Analytical Framework for Austin, Texas*. Describes use of cartographics, optimization, and statistical analyses in developing EMS vehicle siting alternatives for Austin, Texas. 150 pp.

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