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NTIA-SP-80-5 • Simulation Modeling of EMS Telecommunication Systems

Simulation Modeling of Emergency Medical Services (EMS) Telecommunication Systems

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Simulation Modeling of Emergency Medical Services (EMS) Telecommunication Systems

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U.S. DEPARTMENT OF COMMERCE
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PREFACE

This paper develops a general conceptual framework for planning and evaluating time-sensitive server systems. This study has grown out of a larger concern for assisting planners and managers in developing an improved systems perspective when designing telecommunications systems. Even though planners and managers are frequently responsible for some subset of a larger system, an understanding of the overall system assumptions, alternatives, and limitations are necessary for efficient subsystem use of human and material resources.

This study represents an effort to put into operation telecommunications planning techniques by modeling a public safety emergency medical services (EMS) system. This approach seemed most practical because it provided a specific application, yet encouraged planners and managers to adapt the concepts of the model to a variety of related applications such as law enforcement, fire protection, and other time-sensitive server systems.

Even though this study employs computer technology, it is largely the system factoring and programming activity which improves the understanding, discipline, and trust of the systems users, planners, and managers.

This paper was originally a thesis submitted to the Faculty of the Electrical Engineering Graduate School of the University of Colorado in partial fulfillment of the requirements for the degree of Master of Science in Telecommunications.

The author would like to thank the numerous people whose time and efforts helped shape this document. First, I would like to thank my advisors: W. L. Flock, D. N. Hatfield, and S. W. Maley, who provided timely feedback and guidance.

Second, I would like to express my sincere appreciation to the Institute for Telecommunication Sciences of the National Telecommunications and Information Administration, U. S. Department of Commerce, for their support on this project. Special thanks go to Mr. Joseph A. Hull and Mr. John M. Harman for their encouragement and assistance.

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SIMULATION MODELING OF EMERGENCY MEDICAL SERVICES (EMS) TELECOMMUNICATION SYSTEMS

H. David Hunt*

This study explores the application of fundamental computer simulation techniques to the planning and evaluation of an emergency medical services (EMS) system. The study is designed to assist local communication managers and planners in designing, modifying and evaluating their EMS telecommunication system to support the goals and objectives of their emergency medical services (EMS) system.

This study assumes time to be a critical EMS system variable. The time variable is examined by dividing the EMS system functions into nine major processes. Using flow charts these nine processes are then factored into subprocesses for further analysis. In the analysis, each subprocess is assigned a numerical value that is later used in a computer simulation of the system.

The computer simulation language employed in this model is the General Purpose Simulation System (GPSS). The GPSS is a block-diagram language designed to accommodate the discrete nature of the EMS subprocesses. A minimum of user experience is required to understand and program the model using GPSS. Data were assigned to the various subprocess categories so that the computer simulation program could be executed.

Data produced by the simulation model were compared with those data obtained from analytical traffic equations (i.e., Erlang B and C). Flowcharts, tables, graphs and an extended computer listing are included to allow the user to reconstruct the simulation data. In addition, a cross-reference matrix is included as an appendix to relate the model subprocesses to relevant bibliographic references.

Key words: Computer simulation modeling; emergency medical communications; land/mobile radio; public safety telecommunications; telecommunications planning; telecommunications modeling.

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1. THE PROBLEM AND ITS SETTING

1.1. The Statement of the Problem

Emergency medical services (EMS) system planning and design has evolved to a state where we must now develop techniques and examples which would aid system managers and planners in better understanding the process and evaluating the performance of their EMS telecommunication subsystems (See Figure 1-1).

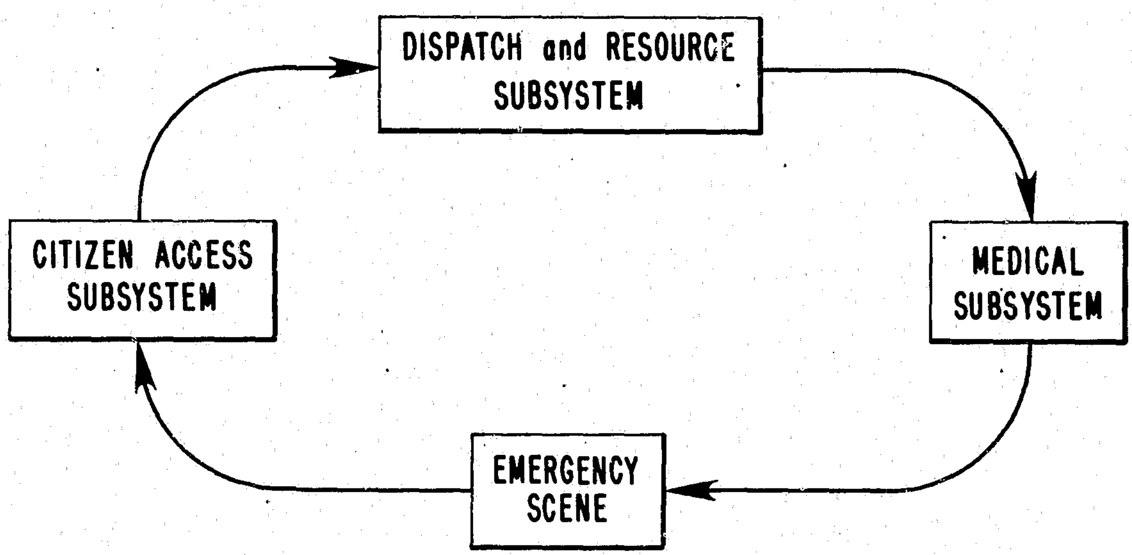


Figure 1-1. EMS telecommunications subsystems.

These three telecommunication subsystems generate the three primary subproblems which are as follows:

The first subproblem. What time delays are incurred in gaining access to emergency medical resources?

The second subproblem. What time delays are incurred in the dispatch of appropriate medical resources to the emergency scene?

The third subproblem. What time delays are incurred before the appropriate medical resources commence Advanced Life Support or some other level of emergency care?

1.2. The Statement of Purpose

The purpose of this study is to conceptualize, structure, and demonstrate an EMS simulation model which can be employed in evaluating the subproblems set forth above.

1.3. The Statement of Objectives

The specific objectives of this study are designed to assist telecommunication managers and planners by providing analytical, simulation, and measurement techniques:

- For better understanding the individual EMS delay components and their impact on the delivery of EMS.
- For the possible adaptation of a simulation modeling technique for evaluating existing or planned EMS telecommunication systems or subsystems.
- For collecting and evaluating delay data on existing EMS telecommunication subsystems.

- For a cross reference between specific EMS delay components and previous applicable research (see Appendix A).

1.4. The Importance of the Study

The lack of efficient emergency medical services in the United States has been attributed largely to the absence of an effective public safety telecommunication system (Owens, 1976). If it is assumed that time is a critical variable in the delivery of pre-hospital emergency medical services, then well-designed, efficient public telecommunication subsystems can play an important role in minimizing the time required to report and respond to an emergency medical event. Knowledge, therefore, of the performance of an existing EMS telecommunications system or the simulation of a proposed alternative, can assist EMS system management by reducing delay to some locally determined minimum level.

1.5. Assumptions of the Study

- Time is a critical variable in the delivery of emergency medical services.
- Time delay is a useful measurement criterion for evaluating EMS telecommunication system performance.
- Analytical and simulation techniques are available which can improve EMS telecommunication system planning, implementation, and operational management.

1.6. Delimitations of the Study

- This study is specifically limited to EMS telecommunication systems. This should not imply that the analytical and performance evaluation techniques are not applicable to other telecommunication systems, but that other systems have unique operational problems which may require special emphasis and treatment.
- Any specific EMS telecommunication system is actually a subset of a larger EMS system; however, for purposes of this study, only the EMS system goals and objectives which relate primarily to the telecommunication subsystems will be considered.

1.7. Methodology of the Study

This is a descriptive study which includes a survey of the current literature and other relevant documentation. A descriptive approach was chosen for this study because it offered the most practical means of analyzing and more clearly defining the relaltionships among the variables in the problem. This study used the descriptive approach:

- To collect detailed information that describes existing techniques and variable relationships.
- To investigate question formulation and answer measurement problems (Weiss, 1972).
- To make comparisons and evaluations (Leedy, 1974).

2. INTRODUCTION TO THE EMS TELECOMMUNICATIONS SYSTEM

The primary goal of the EMS telecommunications system is to provide the necessary communication links so as to minimize the time delay between the occurrence of a life-threatening or crippling incident and the rendering of appropriate emergency medical care and support resources. Most communities and local governments already have a multiplicity of existing telecommunication services and facilities that relates in some degree to that primary EMS telecommunications goal. Managers and planners of EMS systems need to question, understand, and evaluate how these existing telecommunication resources, in a defined jurisdictional and/or operational area, can be modified or augmented in a cooperative way to minimize the delay introduced by the telecommunication system. Before considering any changes, however, the EMS telecommunication managers and planners should make every effort to insure that the proposed telecommunication changes meet the needs of the EMS users and are compatible with the goals and objectives of the overall EMS system.

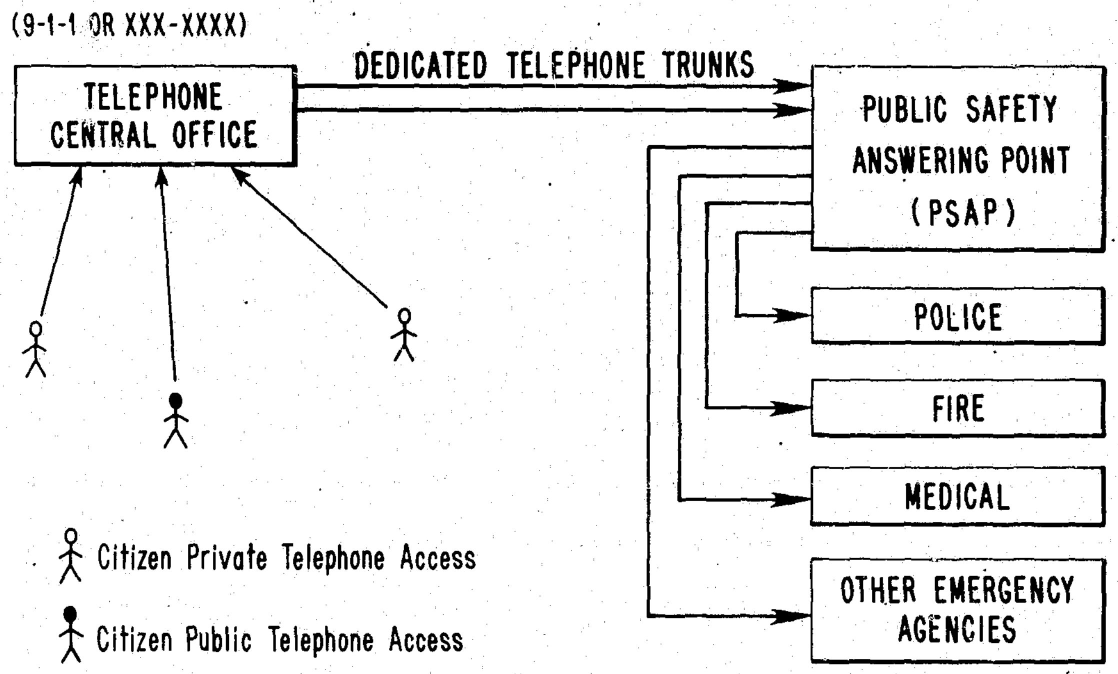
Before proceeding with a more detailed analysis of the EMS telecommunications process, a brief overview of the three telecommunication subsystems will be presented.*

*Those desiring a more detailed account of the EMS telecommunications planning function are directed to Emergency Medical Services Communications System Technical Planning Guide, NTIA SP79-3 available from U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20404 for $5.50 per copy.

2.1. Citizen Access Subsystem

The public telephone network serves as the most readily available means for most citizens to notify public safety personnel of a medical emergency. Citizen access has been improved by the implementation of the universal emergency number, 9-1-1, which theoretically provides access to all public safety agencies in a community or region via a Public Safety Answering Point (PSAP) (see Figure 2-1a). The implementation of 9-1-1 or a single, seven-digit number simplifies the task of emergency access by reducing the number of decisions that must be made regarding the appropriate political jurisdiction to call, the most appropriate agency to respond, and the proper configuration of needed equipment. This places the responsibility for emergency medical resource allocation with a paid, public safety professional and generally reduces EMS system delay. Figure 2-1b illustrates a PSAP where the police answer all emergency calls and then relay, transfer, or refer those fire, medical and other emergency calls to the appropriate public safety agency.

In addition to the public telephone system, some communities have additional citizen access through citizen band radio (Channel 9), radio call boxes (street and highway), commercial radio systems (e.g., utility companies, private bus systems, taxicabs. . .), private and public alarm systems, aircraft radio systems, and amateur radio monitoring. The use and effectiveness of these other citizen access methods is largely determined by the need, leadership and cooperation at the local level.



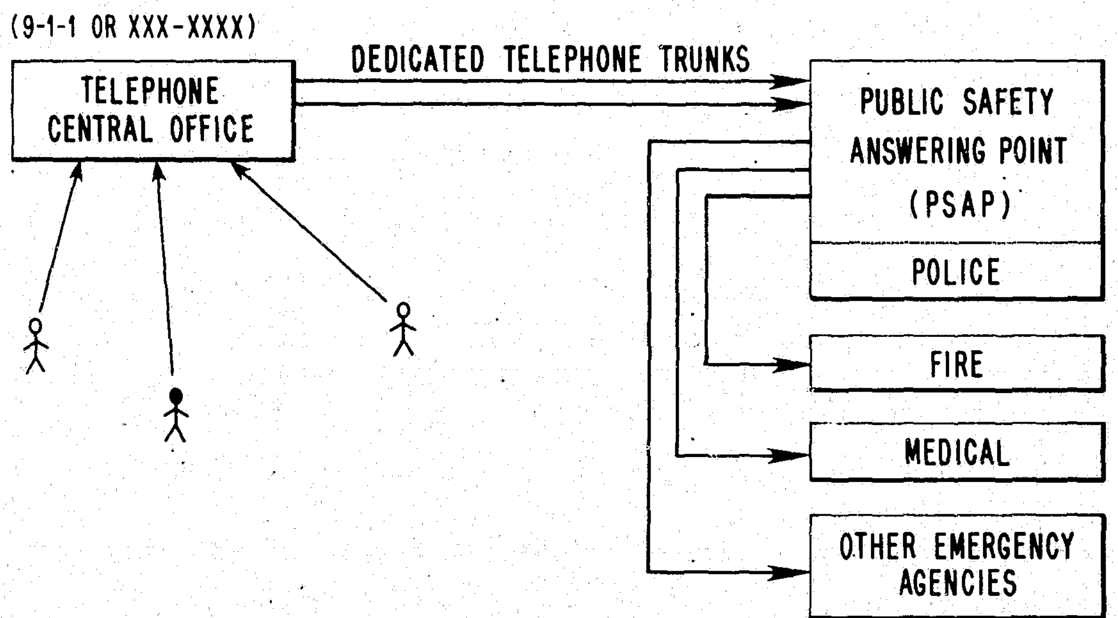


Figure 2-1. Two PSAP configurations.

2.2. Dispatch and Resource Subsystem

Once citizen access has been achieved, response to emergency medical needs should involve the coordination of public safety agencies through a dispatch and resource subsystem. In many instances, a single emergency incident may require a response from more than one public safety agency. In a traffic accident for example, the police may be required for traffic and crowd control, the fire department may be needed to control a gasoline fire hazard or perhaps the extrication of victims from the vehicle, and medical assistance may be needed in the event of injury. The need for multi-agency coordination and cooperation highlights the importance of a carefully planned telecommunications system to minimize delays and optimize use of the various public and private emergency resources.

Operational experience with Public Safety Answering Point (PSAP) systems has shown that approximately 85% of the incoming emergency calls involve law enforcement services, 10% fire services, and 5%, emergency medical services (EMS). However, further analysis of these statistics indicates that some 35% of the law enforcement and fire calls have associated medical injuries requiring an EMS response. These percentages are not intended to serve as system conceptual design criteria, because each local EMS system must collect and analyze its own data; however, they do point out the importance of close public safety agency coordination. In addition, the organizational and technical design of the dispatch and resource subsystem will vary depending on the local needs and on the cooperation of the various agencies in the EMS system (public safety, private ambulance, hospitals, search and rescue...). The specific dispatch configuration will generally reflect this level of agency cooperation in its operational structure and hardware interconnection.

2.3. Medical Subsystem

For purposes of this study, the medical subsystem includes those activities beginning with patient triage and terminating when the emergency medical patient is transfered to an emergency medical facility.

The delay component contributed by the medical subsystem will vary depending on the type of emergency response. For example, if an advanced life support unit is dispatched to the scene of a medical emergency and is authorized to initiate certain advanced medical procedures, the patient may be stabilized at the emergency scene thereby reducing the critical nature of the transit delay to an emergency medical facility. In many cases, this advanced care has been extended to the emergency scene because the necessary medical direction and control is maintained through land mobile radio communications. Conversely, a basic life support unit may not be authorized to initiate certain advanced medical procedures and the patient may not be stabilized until arrival at the emergency medical facility. One of the obvious benefits of advanced care at the scene of an emergency is mitigation of transit-time delay to an emergency medical facility.

2.4. EMS System Delay

As stated previously, the primary purpose of this study is to present analytical, simulation, and measurement techniques which will assist local EMS systems managers and planners in better understanding, defining, and evaluating EMS system delay components.

To set the stage for EMS telecommunications system analysis in the next section, each of the three telecommunication subsystems will be considered part of a process as illustrated in Figure 2-2. Each process will then be further divided, as required, to some sub-process level depending on the degree of detail needed to define the delay component of that particular process. Once the analytical structure of the three major processes has been analyzed and defined, hypothetical or empirical delay values will be assigned to each of the subprocesses to program the simulation model.

Actual subprocess delay times will obviously vary from system to system depending on the geography, urban or rural setting, citizen access facilities, etc. Regardless of the area, however, each EMS system should attempt to define delay values as a target for follow-on system evaluation.

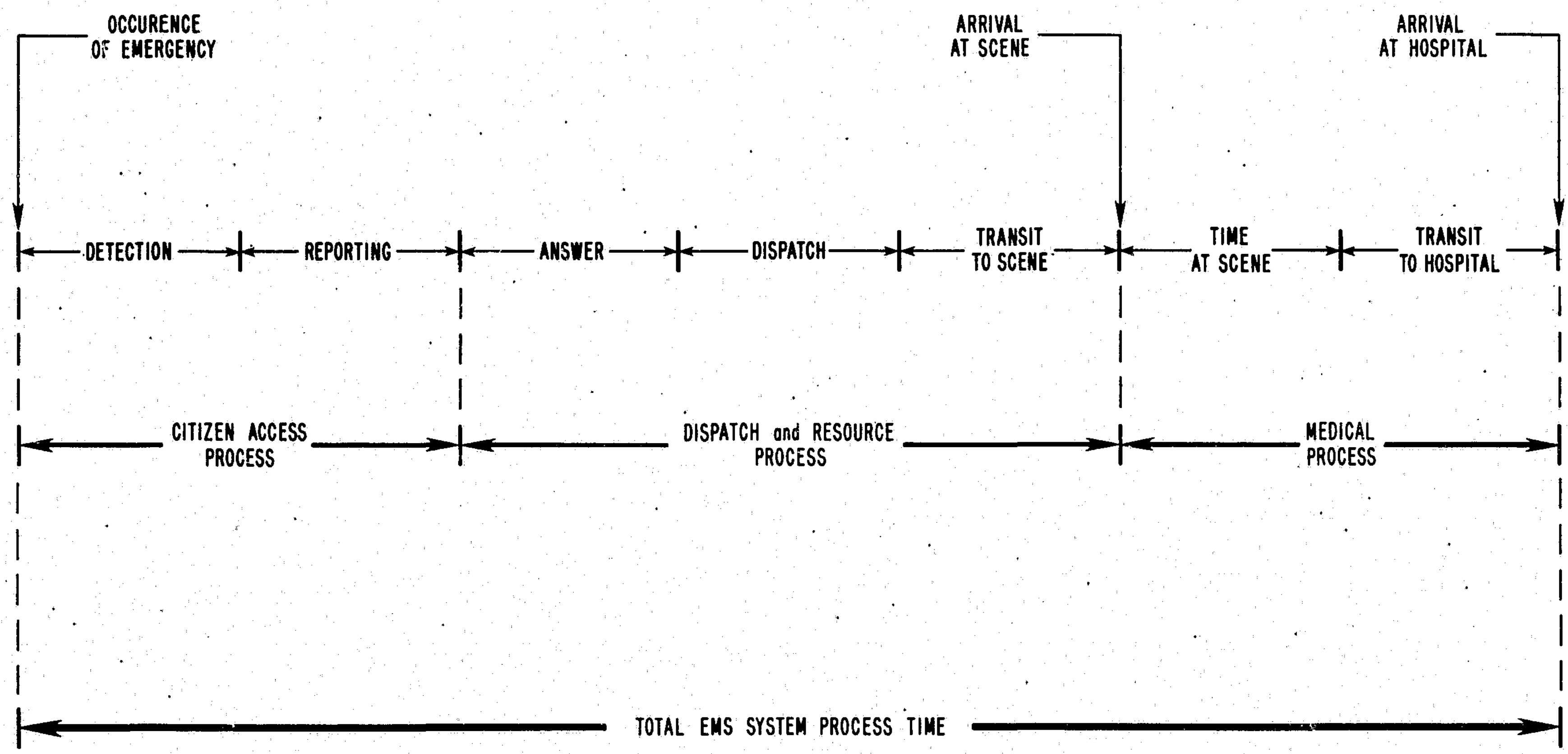


Figure 2-2. Emergency system processes.

3. STRUCTURAL DEVELOPMENT AND ANALYSIS OF THE EMS TELECOMMUNICATIONS SYSTEM MODEL

Developing and analyzing an EMS systems model may be broadly divided into two interrelated tasks:

- o Establishing the structure of the model from the actual and/or conceptualized EMS system.
- o Supplying empirical and/or hypothetical data for analytical and simulation analysis of the EMS system model.

Before proceeding with the analysis, it may be well to note that there is no unique model of any system, including EMS. System users, managers, planners, and researchers interested in different aspects of the same EMS system will perceive different models as amplified and modified by their particular vantage point. Similarly, an individual's perception of the EMS system is not static, because individual model boundaries will change as understanding of the EMS system is modified by human behavior, institutional change, technology, and economic priorities. The model being presented in this study should be viewed as an evolving, analytical tool, something to be modified or expanded by the user to replicate more closely local EMS needs and conditions.

This chapter addresses the structural development of the EMS model and the following chapter discusses stochastic concepts, data collection techniques, data replication and simulation software selection.

The structural development of the model, addressed in this chapter, will employ the techniques of systems analysis. Systems analysis is a visual method of dealing with a manageable amount of information at any given time, so that by degrees, one can ultimately describe large and complex systems in detail. Basic systems analysis symbols utilized in this study are illustrated and defined in Figure 3-1, an overview of the EMS telecommunications process. Note that Figures 4-1, 4-2, and 4-3 have been placed at the end of this document. This placement was employed so that the reader could move more easily from the narrative to the detailed flowcharts without changing or searching for the appropriate page.

An engineering numbering system was employed to insure that the reader may clearly relate to the particular process or subprocess being discussed. In addition, the numbering system has been designed to provide a convenient cross reference to the computer simulation programming blocks in Appendix B and the bibliographic matrix in Appendix A. The following example will serve to clarify the numbering system.

Example: <u>Process P5.2.2</u>

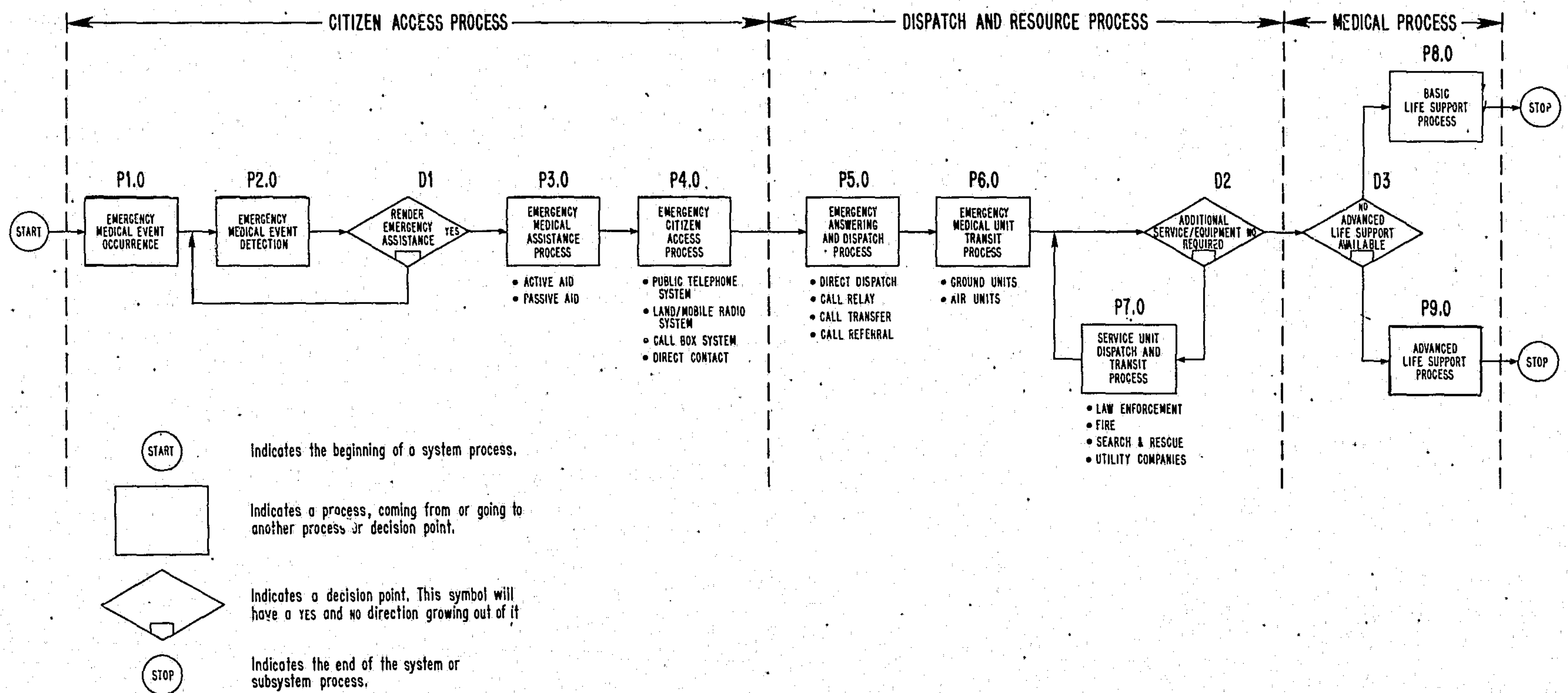


Figure 3-1. Overview of the EMS telecommunications process.

The alphabetic character and number "P5" identifies a primary process within the EMS system. The second number "2" identifies the subprocess (within process "P5") of the EMS system. The third number "2" identifies a further breakout of the subprocess for the purpose of analysis. In this particular example the process breakout is as follows:

- o Process P5.0: Emergency Dispatch Process
- o Process P5.2.0: Call Relay Process
- o Process P5.2.2: Obtain Emergency Information Process.

This example was taken from the Figure 4-2 Flow Chart, Dispatch and Resource Process.

Decision points within the flowchart of emergency procedures are identified as shown by the following example:

Example: <u>Decision Point D1 (P5.2.0)</u>

The alphabetic character and number "D1" identifies this as the first decision block. The number enclosed in parentheses indicates that this is the first decision point in subprocess P5.2.0. This example was also taken from Figure 4-2.

The structural development and analysis of the model begins with an individual discussion of the nine EMS processes (P1.0 through P9.0) illustrated in the Figure 3-1 flowchart. Each process is developed in proportion to its impact on the overall EMS telecommunications process. Since a key aspect of this study is to present an EMS systems perspective, details of existing or current research will not be included in the narrative unless they are highly relevant to the particular process; however, the references have been included in the bibliography and cross-reference matrix in Appendix A.

Before proceeding with the following nine processes, the reader is encouraged to review the Figure 3-1 flowchart which provides an EMS system overview.

3.1. Process P1.0: Emergency Medical Event Occurrence

In this study, emergency occurrences are broadly classified as discrete or nondiscrete. The discrete emergency occurrence is a medical event where the actual emergency incident is clearly defined in terms of time and space, such as an automobile accident. In those nondiscrete medical emergencies which evolve over a period of time, there is greater difficulty for the afflicted individual as well as a second party to detect and/or accept the evolving emergency medical symptoms.

Medical emergencies of special concern to emergency medical systems because they often occur at home or in home and road accidents, are cardiopulmonary failure, hemorrhagic shock, abdominal viscera damage and brain or nervous system damage (Andrews, et al., 1975). Cardiopulmonary failure is the most urgent category of medical emergency, since irreversible brain damage generally occurs within three to four minutes of cardiopulmonary collapse (Gaal, 1966).

3.2. Process P2.0: Emergency Medical Event Detection

The initial detection of a discrete emergency medical event requires basically a person's physical presence and sensory perception. It could be argued that physical presence is not a prerequisite because it is technically possible to extend our senses (i.e., optically, electronically. . .); however, as a practical matter, this study will assume that such apparatus are normally not available at the emergency scene and that physical presence is a prerequisite to the emergency medical detection process.

For the nondiscrete emergency medical event to be detected, it may be necessary that the emergency medical condition reach some threshold before the afflicted individual experiences a sufficient level of discomfort to take some action, or the symptoms generated by the discomfort are recognized by a second party as requiring emergency medical treatment. The probability of a second party's detecting a nondiscrete medical emergency may vary considerably depending on his or her relationship with the afflicted person, knowledge of the symptoms through formal training and/or experience, familiarity with the locally available medical resouces and the methods of gaining access to those emergency resources. A study by R.B. Andrews, et al., (1975) concluded that:

- The decision that emergency medical care is required is made largely in the absence of an accurate diagnosis. At one extreme, apparently minor complaints can be harbingers of life-threatening conditions. At the other extreme, a high level of apprehension on the part of the victim, his family or friends, can result from a relatively minor condition.

- Most people are infrequently faced with medical or surgical emergencies. As a consequence, they have little occasion to develop an accurate understanding of how the emergency medical care system in their community works and how to use it properly. The demands placed on the public and private sectors for emergency care depend, to a considerable extent, on misconceptions and expectations, and lack of knowledge and experience.

The emergency event detection process, although over simplified in this study, demands careful consideration by EMS system managers, planners and researchers. The role of public education in training citizens to recognize emergency medical symptoms and the availability of local emergency medical resources should receive high priority in most EMS systems.

3.3. Decision Point D1: Render Emergency Assistance?

The person detecting an emergency event must make a decision whether to render aid or ignore the emergency. If the decision is to ignore the event, action is delayed until a second person detects the event and so on. Rationalization for persons not rendering aid in an emergency condition is highly complex. In this study, it will be acknowledged that some percentage of individuals will not render aid in an emergency event, creating an additional EMS system delay. Developing data which approximates the detection delay and percentage of individuals who would ignore an emergency event is discussed in the next chapter.

3.4. Process P3.0: Emergency Assistance Process

This process initially involves a decision of whether the person who detects an emergency event renders "active" or "passive" aid. The process of active aid requires a person to stop at the scene of a medical emergency to render first aid, to reduce the possibility of further injury, and/or to assess the need for additional assistance. Passive aid is defined as not stopping at the scene of the emergency but immediately reporting it to a public safety agency.

No value judgment is assigned to the active or passive aid subprocesses because in one case active aid may be most appropriate and in the next case passive may be more appropriate.

3.5. Process P4.0: Emergency Access Process

This process is activated by an individual who has detected an emergency and is attempting to report it to a public safety agency. Because most people are infrequently confronted with life threatening emergencies, few people develop formal plans that effectively cope with such emergencies. This is particularly true if they are traveling in geographic areas unfamiliar to them. This lack of geographic familiarity and the element of surprise places them at a disadvantage regarding timely assessment and reporting of an emergency event. Even in familiar geographic surroundings, many citizens have idealistic expectations of the emergency citizen access system because they have no understanding of the local emergency process.

Citizen access to the emergency medical system has been divided into four broad categories as described below:

3.5.1. Process P4.1: Public Telephone System

This facility is the most frequently used system for notifying a public or private agency of an emergency. Although the public telephone network has many advantages for reporting emergencies to the proper agencies, a number of serious delays are often encountered by the user. Some of these delays are the result of the user's not preparing for emergencies or his/her not being encouraged to do so through comprehensive public safety education programs. Other factors which contribute to emergency telephone system delays often include poorly conceived and defined jurisdictional boundaries, poor cooperation among public safety agencies, antiquated public telephone equipment and other political, social and economic problems. The individual who is not aware of certain emergency system constraints may have a rather idealistic notion of how it functions, further adding to anxiety and frustration in an actual emergency. These delays are generally exacerbated when the emergency is detected and reported by a visitor or newcomer.

The specific delay components that have been included in this model to replicate the public telephone system delays are for the most part symptoms of the above more far ranging societal problems; however, the symptoms must be considered in evaluating emergency system performance. Delay components include:

- o The delay in locating a public or private telephone.
- o The delay in determining the jurisdiction and appropriate public safety agency telephone number.
- o The delay in locating coins if required by the public telephone.
- o The delay in redialing and locating more change if the wrong telephone number is reached.

Some of these delays have been mitigated by implementation of a single emergency telephone number such as 9-1-1. This concept is attractive because the citizen needs only to remember a single emergency telephone number. Other technological changes such as "selective" telephone routing allows emergency system managers and planners to accommodate the local interagency technical, political and social idiosyncracies.

3.5.2. Process P4.2: Land Mobile Radio (LMR) System

The use of LMR to reduce the notification delay of emergencies has met with mixed success. Research has revealed serious political, administrative, operational, and economic problems. A specific research study sponsored by the Department of Transportation and conducted by the University of Michigan Highway Safety Research Institute offered some insights into the problems of using LMR for emergency notification. One aspect of the study compared the following two citizen access methods:

- o System 1: Private citizens using public telephones
- o System 2: Randomly dispersed vehicles (buses, dispatched trucks, police cars, etc.) having voice LMR, which happen by chance upon emergencies.

Paraphrasing from Systems Analysis, Inc., Special Report 72-2, it was concluded that 20% of all vehicles would have to be equipped with voice LMR in order for System 2 to effect a 1-minute reduction in mean access delay. .. It is unlikely that System 2 will be a valuable link in the citizen access process in the near future.

In addition to the low probability that an LMR equipped vehicle would detect the emergency event, certain other factors could add substantially to LMR access delay such as:

- o The inability of the detecting LMR unit to contact its dispatcher or relay the emergency information through a second LMR unit.
- o The inability of the detecting LMR unit to capture a radio channel; radio traffic conditions or other modes of interference are the disabling factors here.

Most nonpublic safety LMR channels are not monitored by the public safety dispatch systems. Public safety agencies generally rely on some private dispatcher or other LMR operator to capture the emergency information and relay it through the public telephone system. Because the number of LMR channels is limited, and because public safety budgets are limited and other cost/benefit considerations can be restricting, it is not likely that a change in policy is justified. Some public safety agencies, however, do monitor citizens band (CB) channel 9, but many prefer that volunteer groups (such as Radio Emergency Associated Citizens Teams (REACT), the Affilitated League of Emergency Radio Teams (ALERT) or the Citizens' Radio Watch) capture the emergency information and relay it via the public telephone system. A CB effectiveness evaluation is being conducted by H.F. De Francesco, et al. (1977) in a New York state region comprising seven counties. The following objectives were established for the evaluation project:

- To measure the magnitude of changes brought about through the use of CB radios by the New York State Police
- To evaluate whether these changes are statistically significant
- To measure the impact these changes have on highway safety and on public participation
- To identify and measure the cost/benefits associated with the changes.

Since the study was not yet completed, the research results are not yet available. The results however, may be less important than the planning and implementation strategy set forth by De Francesco. Generalizing from one EMS area to another in the LMR environment is probably less productive than experimenting with an EMS idea at the local level because, with the right alinement and mixture of human resources, leadership and planning the LMR technology may reduce local access delay.

3.5.3. Process P4.3: Call Box System

This method of access is primarily employed on selected, limited-access freeway systems. These freeway call box systems are generally monitored by freeway authorities, highway maintenance personnel, state patrol, or the like. This method of EMS access requires the emergency information to be relayed to the appropriate public safety agency via the public telephone system or some other land-line configuration (i.e., automatic ring down, intercom. . .).

The traditional fire call box systems still located in some urban areas have been, for all practical purposes, outdated by the public telephone system.

Although nationally the call box systems have had relatively little impact on emergency citizen access, certain local areas providing emergency services to major highway systems have found them an important citizen access point.

3.5.4. Process P4.4: Direct Agency Contact

In this method of access the individual locates the public safety agency and directly reports the emergency to agency personnel. These personnel then relay the emergency information to the appropriate agency who directs the resources to the emergency scene. This method of access generally adds delay because of such factors as increased travel time by the individual, locating the proper public safety agency, the present location and design concepts of public safety dispatch centers, and the added step of relaying emergency information through agency desk personnel.

This method is included in this study because some of the constraints outlined above may not be a problem in a small city or town.

3.6. Process P5.0: Emergency Answering and Dispatch Process

This process is initiated when the emergency call operator is signaled (i.e., ringing telephone, automatic private line, buzzer. . .) and thereby alerted to a potential emergency. The message received from the caller serves as a middle link between the emergency and the necessary decisions to be made during the dispatch and resource allocation process. A recent study by G.B. Keller and R.R. Lanese (1977), hypothesized that certain variables in emergency messages were directly related to the dispatching decisions and the subsequent actions of the EMS personnel. Some of the variables which they addressed were message content, interaction factors (message characteristics), and system status factors (time, day, busy status).

One of the elements of their study addressed the relationship between the emergency caller's perception of the emergency event and information gathered by the other EMS processes. This information was then analyzed to determine how the dispatch decision processes might be improved. This middle link between the emergency caller and emergency call answerer has the potential for generating numerous follow-on EMS system delays if the emergency call operator is not trained to question and probe for key decision-making information.

As illustrated in Figure 2-1, the role of the Public Safety Answering Point (PSAP) is to facilitate the flow of emergency information between the caller and the appropriate responding agency.

The manner in which the information is routed to the responsible agency varies with the jurisdictional, operational, and organizational requirements of the EMS area being served. The four basic operational methods are direct dispatch, call transfer, call relay and call referral. Most systems comprise a combination of several of these methods to adapt to variations in the levels of cooperation, centralization, and consolidation between and within the participating agencies in the system (Stanford Research Institute, 1974a). Figure 3-2 illustrates the information flow for each of these operational methods, which are individually discussed below.

3.6.1. Process P5.1: Direct Dispatch Process

In the direct dispatch process, current literature has defined that the emergency answering and dispatching functions are collocated. Examples offered in the literature indicate that the public safety

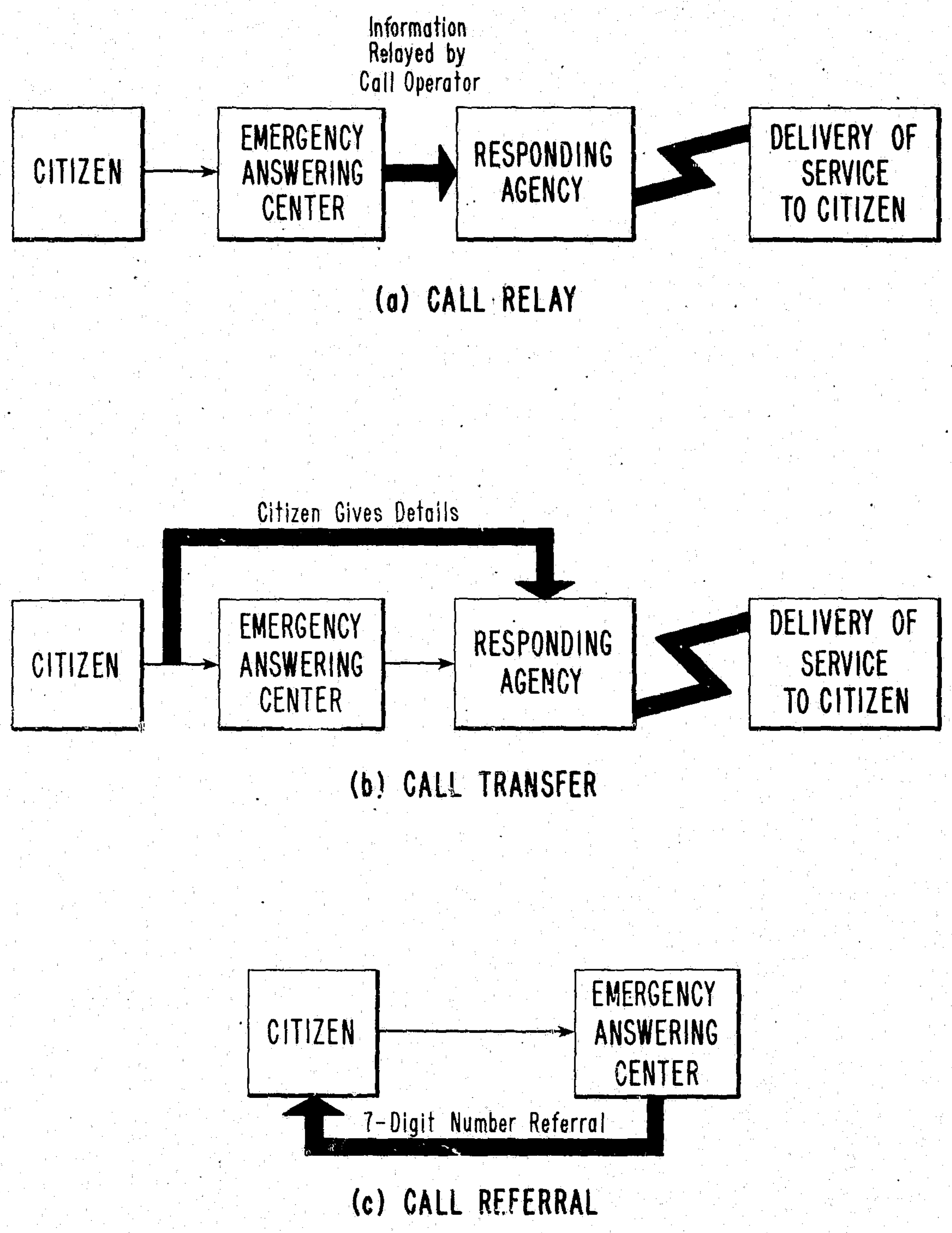


Figure 3-2. Emergency call answering configurations.

answering point (PSAP) might be collocated with a centralized multi-agency dispatch center processing emergency calls for law enforcement, fire, emergency medical services and others, or it might be collocated with a single agency providing only one type of emergency service.

A literal interpretation of direct dispatch implies that the PSAP call operator who answers the emergency call also directly dispatches the appropriate resources. This is referred to as a one-stage direct dispatch process. If a second person is added to the process and assumes responsibility for some aspect of it (i.e., dispatching), the setup is now referred to as a two-stage direct dispatch configuration. This two-stage direct dispatch configuration, however, is very similar to the call relay process (discussed in 3.6.2.). This similarity raises a question regarding the significance of the collocation requirement in defining direct dispatch. The designer/planner must ask: Does collocation mean immediately adjacent, in the same physical room or building, or administratively related? Operationally, does collocation have any significance if the transfer of information (from the call answerer to the dispatcher) is performed electronically?

There are some definite advantages to single stage direct dispatch because the message link between the emergency caller and agency dispatcher are theoretically optimized; however, that advantage is often overshadowed by other operational and political factors. If collocation is not considered a significant point in defining direct dispatch, at least from a functional standpoint, it might then be asked, what are the fundamental differences between the two-stage direct dispatch processes and the call-relay process? This study will assume that there are no basic differences once the call answering and dispatching functions are divided in the direct dispatch processes.

3.6.2. Process P5.2: Call Relay Process

In this process, the emergency call answerer records all of the pertinent data provided by the emergency caller. This information is then forwarded to the dispatcher who has the responsibility of allocating and coordinating one or more agency resources depending on the local configuration of the dispatch system.

Call relay has the operational and political advantage of being able to leave the dispatch function under the control of the individual agencies if multiagency dispatch is not acceptable. If dispatch control is left with the individual agencies, however, more explicit call answering policies are usually dictated by the involved agencies. A simplified illustration of this concept is shown in Figure 3-2a.

3.6.3. Process P5.3: Call Transfer Process

When this process is employed, the emergency-call answerer requests from the caller information on the type and location of the emergency.

Once this basic information is received, the caller is electronically transfered (switched) to the call answerer or dispatcher of the appropriate, responsible service.

The call transfer process is often viewed by public safety agencies as more desirable because the agencies are able to maintain their identity with the citizen and to screen their own emergency calls. One of the primary disadvantages of this method is that the citizen may become frustrated when asked to repeat certain details of the emergency incident. A simplified illustration of this concept is shown in Figure 3-2b.

A more sophisticated transfer process known as "selective" routing has been developed which automates this technique. A computer performs certain telephone switching functions which connect the caller with the appropriate public safety agency.

3.6.4. Process P5.4: Call Referral Process

This process is activated when the emergency reported is not immediately life or property threatening and requires only the response of an agency not directly affiliated with public safety (such as a utility company, U.S. Forest Service, Coast Guard, FBI, or the like). The emergency call answerer provides the caller with the appropriate seven digit telephone number and then the caller is required to contact the proper agency directly.

A simplified illustration of the call referral process is shown in Figure 3-2c.

3.7. Process P6.0: Emergency Medical Unit Transit Process

This process is activated after the receipt of a dispatch message from a public safety agency or, in some cases, from private dispatch services. The dispatch method may employ LMR or some configuration of land-line to a medical unit station such as a fire station, private ambulance service or volunteer ambulance company. Volunteer systems may also use LMR paging and/or special public telephone options (i.e., all call) to alert and dispatch their personnel.

This process commences when the medical unit is enroute and terminates with the completion of the emergency scene initial evaluation. Intervening delays include normal travel time, traffic congestion, inclement weather, incorrect location/address, lack of traffic control and/or crowd control at the emergency scene, medical unit mechanical failure, and so on. Several research studies have developed techniques for optimizing the number and location of medical units in an EMS geographical area, these references appear in the bibliography and subprocess matrix in Appendix A.

During transit to the emergency scene, the medical unit requires LMR communications with the agency dispatcher. In addition, the dispatcher should coordinate and assign an LMR medical control channel for communications between the mobile medical unit and the medical facility.

3.8. Decision Point D2: Additional Service/Equipment Required?

A decision is required after the initial emergency scene evaluation to determine if resources in addition to those already dispatched are needed for such services as patient extrication, search and rescue, fire hazard control, wrecker service, additional transport units, utility company support, highway maintenance, and the like. If such services are required, an additional delay is imposed by process P7.0, the service unit dispatch and transmit process. If additional service/equipment is not required, the process moves to decision point D3.

3.9. Process P7.0: Service Unit Dispatch and Transit Process

This process is activated by the receipt of a request for additional services from the emergency scene to the agency dispatcher. The dispatcher then notifies the appropriate service unit via LMR or some configuration of land-line as to the required service and location of the emergency. "Service units" in this study refers to those resources which would act in a support capacity to the emergency medical process. For example, if a medical unit reaches the scene of an automobile accident and requests extrication services to free the accident victim from the vehicle, the responding agency is the "service unit".

The service unit process commences when the agency dispatcher acknowledges the service unit request from the personnel at the scene of the emergency. That process terminates when the service unit satisfactorily completes the requested service. Intervening delay components in this process include service unit dispatch, service unit avaiability, service unit travel time, traffic congestion and so on.

3.10. Decision Point D3: Advanced Life Support (ALS) Available?

Those EMS systems which have both basic and advanced life support capabilities must have a decision-making protocol to select the appropriate medical response. This decision is normally made by the agency dispatcher.

3.11. Process P8.0: Basic Life Support (BLS) Process

This process includes all delays from patient triage at the emergency scene, through patient transfer to a medical facility. The BLS process is characterized as emergency first aid that includes basic airway management, shock management, application of cardiopulmonary resuscitation (CPR), hemorrhage control, initial wound care, fracture stabilization, extraction and transport techniques, and other similar first aid procedures.

In this process, LMR communication between the BLS personnel and the medical facility transmits patient vital signs and other useful diagnostic data to allow the receiving medical facility to be more fully prepared to receive the emergency patient. Since BLS procedures do not normally include intraveneous infusion or administration of drugs, the more sophisticated medical procedures are delayed until the patient is actually transferred to a medical facility.

3.12. Process P9.0: Advanced Life Support (ALS) Process

Advanced life support extends basic life support by including advanced airway management, intraveneous infusion, drug administration, defibrillation, cardiac monitoring, control of arrythmias and post-resuscitation care. These more advanced procedures which ALS personnel are trained and authorized to administer, increase the probability of stabilizing certain categories of patients at the emergency scene or en route to the medical facility; thereby, mitigating the effects of the delay in transit to the medical facility.

Usually ALS personnel are assumed to be under the direction of a physician who is present, or who is in communication with ALS personnel, or who has issued standing orders to deal with certain types of emergency medical patients.

Because of the mobile nature of the emergency medical environment, LMR technology has been quite naturally a key element in EMS development. The actual use, however, of LMR between the physicians and ALS personnel will vary from system to system depending on such factors as:

- The relationship and confidence between the physician(s) and ALS personnel
- The experience of the ALS personnel
- The use of standing orders or protocols
- The real and perceived quality of ALS training
- The amount of responsibility accepted by ALS personnel

- The amount of authority delegated by the physician(s).

Regardless of the ALS strategy, an LMR coordination channel between a medical facility and the ALS personnel is a most critical communications link for operational and legal reasons.

4. SIMULATION OF THE EMS TELECOMMUNICATIONS MODEL

The demonstration model in this study employs a dynamic, stochastic simulation technique that accurately accounts for the passage of time and is capable of closely representing the stochastic nature of the EMS environment. For EMS system performance evaluation, the simulation technique was considered more appropriate than the purely analytical approach because of the large number of EMS system subprocesses, interrelationships and service distributions.

Simulation techniques are commonly categorized as either continuous or discrete. Simulated systems in which changes are predominantly smooth, are called "continuous" systems. Conversely, those in which changes are predominantly discontinuous are referred to as discrete systems. Few systems are wholly continuous or discrete; however, as the various processes in an EMS system are subdivided, the sub-processes take on the appearance of a number of discrete steps. Techniques which are designed to accommodate stochastic, discrete events are called discrete simulation models. Such models are ideally suited for implementation on digital computers.

Since any modeling technique places certain limitations on the degree to which a particular system can be replicated, the following subsections will discuss the assumptions and limitations imposed by the selected simulation language.

4.1. Simulation Language

A number of discrete simulation programming languages are commercially available. The software selected for this study is the General Purpose Simulation System (hereafter referred to as GPSS), a language developed by International Business Machines Corporation. The GPSS is both a language and a computer program. As a language, it has a well-defined vocabulary and grammar with which certain types of system models can be unambiguously described. As a computer program, it interprets a model described in the GPSS language, thereby making it possible to conduct experiments with the model on a computer (Schriber, 1974). GPSS has been written specifically for users with little or no programming experience. This simplification of GPSS results in some loss of flexibility compared with SIMSCRIPT or the more general purpose languages such as FORTRAN or PL/1; however, a survey by D. Teichroew and J.F. Lubin (1966) found no evidence that either GPSS or SIMSCRIPT was restricted to any particular type of system. They concluded that both GPSS and SIMSCRIPT were general enough to be equally applicable to a wide variety of systems. The GPSS generally requires greater storage and execution than SIMSCRIPT or the other general-purpose languages; however, with the decreasing cost of computer storage and improved throughput capabilities of current computer hardware, these factors are probably no longer serious constraints. A more significant justification favoring GPSS is the savings of human resources and the reduction of project time. The GPSS has excellent diagnostics at the source language level, at compiler time, and during the simulation. These diagnostics allow the user to debug and check the programs quickly (P.A. Bobillier, 1976). Debugging stochastic simulation models can be very complex and time consuming if complete diagnostics are not provided. Another factor favoring GPSS is the level of user maintenance and the number of computing facilities which can support it.

A common tendency in modeling is to become so involved with the model that the original underlying assumptions and limitations are obscured. P.A. Bobillier, et al. (1976) developed a list of four general limitations common to simulation modeling:

- o Simulation may not give the optimum solution of a problem but is quite useful in comparing alternatives.
- o The validation of completed simulation models can be very difficult because of stochasticity and autocorrelation.
- o The accuracy of simulation results will be somewhat unpredictable if a limited number of samples are simulated
- o Simplifying assumptions made in building the simulation model structure must be carefully understood so that the limits of generalization are known.

These are not exhaustive, but they represent some of the primary pitfalls which are common to modeling in general and simulation in particular.

In reviewing the literature for this study, several simulation models were found that had been employed in law enforcement and fire but only one model was found to have a systems application in EMS. This particular model was documented by R.B. Andrews, et al. (1975), in a study funded by the U.S. Department of Transportation. The model was initially programmed in SIMSCRIPT and later rewritten in PL/1 to eliminate software and computer support problems. Detailed documentation of the simulation model was not reviewed, but the outline contained in the U.S. Department of Transportation study had a number of interesting program options.

4.2. Programming the Model

The GPSS can be described as a block-diagram language which lends itself to the analytical process used with flowcharting. Flowcharts provide a basic piece of GPSS programming documentation as well as a graphic roadmap for understanding the model. The process of building flowcharts (Figures 4-1, 4-2, and 4-3) and obtaining extended computer printouts (Appendix B) were designed to provide this documentation. It should be noted, however, that there is not an exact one-to-one correspondence between the flowchart blocks and the extended computer printout. In an effort to reduce the confusion involved in comparing the flowcharts and the computer program, the process and decision block numbers on the flowcharts have been included in the right-hand column of the extended computer program listing (Appendix B). In addition, those GPSS program steps which do not appear in the flowcharts are identified in two ways in Appendix B:

- o GPSS OPR - indicates a GPSS operation which is required for program operation and implied in the system operation
- o GPSS STATISTICS - indicates a GPSS program step required for the gathering of simulation model statistics.

In developing the demonstration model, only the basic GPSS programming blocks were used. This approach was taken to reinforce the analytical value of the model by retaining a relatively close one-to-one correspondence between the model flowchart and the extended computer program. This can be a somewhat inefficient programming approach but was considered an important tradeoff in this case. It is assumed that if EMS personnel intend to employ simulation modeling in their local EMS system, they will consult with computer programming personnel. Once a basic understanding of the simulation model is developed by the EMS managers and planners, the programming can be modified to incorporate as many options as deemed appropriate to replicate more fully their local EMS system. An excellent GPSS text authored by Thomas J. Schriber (1974) is recommended for self study and as a reference. Also of value as a reference text is the General Purpose Simulation System V User's Manual, available from International Business Machines Corporation.

4.2.1. GPSS Clock Operation

GPSS is an event-oriented simulation model. Once a specific event is completed, the program automatically determines the next event to occur and updates the simulation clock by adding, to the present time, the time until the next event. The program then proceeds with the set of operations associated with that event (Larson, 1971). This ability to compress hours, days, and weeks into a few seconds of computer time is one of the primary advantages of simulation modeling.

There are several GPSS clock features which require greater elaboration.

- o The GPSS clock registers only integer values. This means that events can only occur at whole time values in GPSS models.
- o The unit of time which the clock registers is programmed by the user. The user is responsible for deciding the smallest time unit required to reflect realistically real-time system events in the model. The user must then take care to express all time data in terms of this smallest unit. The demonstration model in this study uses the second as the smallest unit, so all data are reflected in seconds, unless noted.
- o GPSS is a "next event" simulator as noted previously. Potential clock readings are

skipped when no events are to take place at those times (Schriber, 1974).

4.2.2. Random Number Generator

The ability to draw values from uniform and nonuniform distributions is an integral part of modeling stochastic systems. The modeling process begins with a function which, when called, generates as its value a number drawn at random from a population uniformly distributed over the interval from 0.0 to 1.0. Such a function is simply referred to as a random-number generator (Schriber, 1974). There are eight distinct sources of uniform random numbers in GPSS. These random-number sources are a predefined part of the processor itself and are identified as RN1, RN2. . .RN8. Care must be exercised in the programming of random-number functions to insure that the initialization and seed selection replicate as closely as possible the actual system being modeled. The application of random-number generators will be discussed later in this chapter.

4.3. Model Analysis and Data Collection

Once the structure of the model has been defined, data can be assigned to the various subprocesses. The data selected should replicate as closely as possible the system being simulated; however, EMS system managers and planners must be sensitive to the data collection problems, cost, and other factors which may compromise the simulation process.

The assignment of numerical values to the various decision and delay points in the model can be drawn from empirical or hypothetical data. In practice, the numerical assignment is generally a combination of the two sets. Factoring the assignment of values into subprocesses has the advantage of focusing on more discrete components of the total system. The danger of this process, however, is accepting the output of the simulation model without a careful analytical and intuitive self-check. Section 5 will discuss certain analytical techniques which can assist the user in verifying and validating his/her model. The user is encouraged to employ intuition and analytical self-checks to avoid a ritualistic application of simulation modeling.

A review of the EMS research literature indicates that the majority of the studies have not specifically addressed the various citizen access subprocesses (especially P1.0, P2.0, and P3.0 in this study), or if addressed, have been treated as a single event (see R.B. Andrews, et al., 1975). As a result of this research void, very little data are available with which to make comparisons or judgments. This would appear to be a fertile EMS research area, one in which the delay components are very critical to certain types of emergencies.

The decision and delay values used in this study were not derived from rigorous research but were reviewed by EMS personnel to assure that the values were reasonable approximations of those which could be found in an actual EMS area. As noted, the intent of the included values are for demonstration purposes only and in no way should be construed as standards for EMS design criteria. The number and complexity of interrelationships which exist in EMS systems dictate that each local EMS area must define its own subprocess values based on geography, population, political boundaries, human and economic resources, agency cooperation, weather conditions, and so on. This should not imply that there are no common values, but that EMS system managers and planners should understand why they are selecting a particular value, even if it is a crude approximation.

To assist local EMS managers and planners in this task, a matrix has been included as Appendix A. The intent of this matrix is to provide a cross reference between specific process/decision point blocks and related research material. These references are not necessarily exhaustive, but the additional citations in the bibliographic references list should provide the necessary audit trail for most important research contributions. In addition, the Appendix A matrix provides a list of the process/decision point values for the demonstration model and blank columns for the user to insert local EMS system values.

The remainder of this section will analyze each of the subprocesses and discuss particular problems involving data collection, subroutines, and other factors which are pertinent to a particular subprocess. While reviewing this section, the reader is encouraged to use the appropriate figure (i.e., Figure 4-1, 4-2, or 4-3) in following the narrative. These figures are located at the rear of the document.

4.3.1. Process P1.0: Emergency Medical Event Occurrence

The generation of emergency events which replicate those occurring in the actual EMS area is critical to a simulation model because it defines the emergency arrival patterns for subsequent processes within the model. The usual way of describing a service arrival pattern is in terms of the interarrival time, defined as the interval between successive arrivals. In addition, when the arrivals vary stochastically, it is necessary to define further the probability functions of the interarrival times. A common probability function which has been used to describe many different phenomena is the Poisson formula. This distribution can be useful providing that the assumptions underlying this formula are representative of the actual system being simulated. The Poisson formula assumes that:

- o The interarrival times of emergency incidents within the EMS area are independent of one another. For example, this assumes that an automobile accident on the freeway and a heart attack in a residential suburb are not related.
- o The probability of two or more emergency incidents occuring simultaneously in the same EMS area is negligibly small. In other words, the probability of a zero interarrival time is assumed to be highly unlikely.
- o The probability that an arrival occurs during a small time interval is proportional to the size of the interval.

These assumptions appear to be compatible with most EMS area conditions except major disasters such as tornados, earthquakes, chemical spills, nuclear radiation or the like. Under disaster conditions, the assumptions would no longer be representative of the arrival patterns and the simulation model would not replicate system performance. Under such conditions, the system would likely be saturated and perhaps partially destroyed, making system performance very difficult to predict. If these Poisson assumptions can be accommodated within the exceptions noted above, a simulation model can be programmed which describes the distribution of the emergency incident arrival rate. The distribution is shown in the following equation:

$$P_k(T) = \frac{e^{-\lambda T}(\lambda T)^k}{k!}, \quad k = 0, 1, 2, \ldots \tag{4.1}$$

where,

$P_k(T)$ = probability that exactly k arrivals will occur during a time interval of duration T

λ = mean arrival rate per unit time

e = base of the natural logarithms.

When a Poisson arrival process is to be simulated, it is not arrival rates which are of direct interest; instead, it is the corresponding interarrival times which must be known. Equation (4.1) can be manipulated to produce the associated distribution of interarrival time. The result is called the exponential distribution. When arrival rates are Poisson distributed, the corresponding interarrival times are exponentially distributed (Schriber, 1974). In GPSS, the equation which defines the sampled interarrival times is shown in (4.2).

$$IAT_{sample} = (IAT_{avg}) [-\log e (1 - RN_j)] \quad (4.2)$$

where

IAT_{sample} = sampled interarrival time

IAT_{avg} = average interarrival time in effect

RN_j = a selected random number generator

$\log e$ = natural logarithm operation.

To generate an IAT sample the user must specify the three variables in the equation (4.2).

- o The average interarrival time in the time units selected for the simulation model. In this model the time would be expressed in seconds.
- o The desired GPSS random number generator (e.g., RN1, RN2. . .).
- o The GPSS standard exponential function or a modified function based on local service area empirical data.

For practical purposes, once the user has selected a random number generator and exponential function, only the average interarrival time need be changed to simulate different emergency system arrival rates. The average interarrival times will vary depending on the hour of the day, week, and month, requiring that the simulation model be redefined so that it closely approximates those same interarrival rates found in the actual EMS area. Determining the actual number of medical emergencies that occur in a defined EMS area, however, is difficult because some citizens request emergency assistance from public safety agencies, others may go directly to an emergency medical facility or clinic, still others may die at home or some other location before emergency aid is requested. Thus, to collect these data for a specified EMS area will require a clear understanding of what is meant by a medical emergency and a knowledge of the various agencies and institutions which act as entry points for emergency medical incidents.

4.3.2. Process P2.0: Emergency Medical Event Detection

The delay between the occurrence of an emergency medical event and its detection depends on such factors as location, weather, human physical presence, and many of the elements embodied in EMS public education and training.

The delay involved in detecting an emergency medical event is not deterministic. If not deterministic, however, what type of distribution most closely replicates it? G. A. Mihram (1972) warns that care must be taken in model development to ensure that the randomness introduced into a stochastic simulation model is appropriate and in accord with the stochasticity encountered in the modeled system itself. Ideally a simulation model should use randomly selected data from the system being replicated. A survey of the literature failed to reveal any research which evaluated this delay process. In the absence of any known studies, the emergency detection process was evaluated using the Poisson assumptions to determine if that distribution could be used as an approximation for initial modeling purposes. In evaluating the Poisson assumptions, no primary problems were encountered and it was conditionally accepted for the demonstration model in this study. The user, however, is encouraged to analyze carefully the emergency detection process and to collect empirical data from his/her EMS area before accepting the Poisson distribution.

When an emergency event is generated in P1.0 (Emergency Medical Event Occurrence) and moves to process block P2.1 (Emergency Medical Event Detection), it is delayed by a holding time which simulates the detection delay. The detection delay is generated by the following equation in GPSS:

$$D_{sample} = (D_{avg}) \, [-\log_e(1-RN_j)] \tag{4.3}$$

where

D_{sample} = delay sample

Davg = delay average

RNj = a selected random number generator

log e = natural logarithm operation.

To generate a D_{sample} the user must specify the three variables in equation (4.3).

- o The average emergency detection time, in the time units selected for the simulation model. In this model the time would be expressed in seconds.
- o The desired GPSS random number generator (e.g., RN1, RN2, . . .) which was not the same seed as that used in P1.0.

- The GPSS standard exponential function or ideally a modified function based on local empirical data.

Similar to P1.0, once the user has selected a random number generator and exponential function, only the average interarrival delay time would be changed to simulate different emergency system detection delay rates. The average interarrival delay times will obviously vary depending on the hour of the day, week, and month. Clearly such factors as location, weather, sight distance, and so on, must be carefully considered if the model is to replicate the local EMS service area. Data collection techniques for determining interarrival detection times can be quite complex and time consuming, however, some concepts and perhaps existing data may be available from city and state traffic engineering personnel. Data required for highway and traffic signal design are closely related to certain aspects of emergency detection.

After the event leaves process P2.1, it enters decision point D1(P2.0). This decision point was included to account for those emergencies which go undetected or unreported and events associated with people who either recover without seeking outside assistance or die.

4.3.3. Decision Point D1: Render Emergency Assistance?

Once the emergency event is detected, the person who detected the event must decide whether to render assistance or ignore the event. One GPSS block which allows an event to be chosen at random from two possibilities (i.e, render aid or ignore) is the transfer block in the statistical transfer mode. If the user assigns a value of .25 (25%) to the transfer block, the results over the long term would be that 25% of the emergency events entering the D1 transfer block will transfer back for redetection and the additional delay involved in that process. It is probable, in this model, that an emergency event could be recycled more than one time. The remaining 75% of the emergency events, over the long term, would proceed sequentially through D1 to the next process. In GPSS, the transfer block is graphically represented by the "diamond" or traditional "decision" block.

The techniques and existing research for gathering data and finally quantifying the number of individuals who fail to report detected emergencies are not well developed. Studies have been conducted on emergency bystander behavior which might offer some assistance in approaching this problem. These studies are referenced in Appendix A and the Bibliography. If questionnaires and/or interviews are used to collect these data they must be carefully designed because most citizens would be reluctant to admit that they did not render aid in a medical emergency. In approaching this data collection problem, the EMS managers and planners are encouraged to review carefully the behavioral aspects of not responding. Ronald A. Howard (1973) breaks such a decision into three preference categories: The first kind of preference is value assignment; the second, time preference; and the third, risk preference. Analyzing the detection problem from these three perspectives may provide ideas for data collection techniques and also EMS public education programs to increase the probability of reporting detected emergencies.

For purposes of this simulation model, it was estimated that 25% of the persons detecting an emergency would not report it, and therefore a subsequent detection would be necessary. This selected value represents the peak hour simulation period. This percentage would have to be redefined for other periods of the day, week, month, and season.

4.3.4. Process P3.0: Emergency Assistance Process

Data required for this process involve the percentage of persons rendering active or passive aid, and those using private resources (i.e., private automobiles, . .) instead of requesting public safety resources. Certain data collected for processes P1.0 and P2.0 should be helpful in assigning the decision point values in the emergency assistance process.

P3.0 employs several blocks (P3.1, P3.2, P3.3, and P3.4) which use uniformly distributed delay times rather than nonuniform distributions discussed in P1.0 and P2.0. In GPSS, uniform delay is expressed as $A \pm B$. Where A is defined as the average delay time and B is defined as the half-width of range over which the delay is uniformly distributed. For example, if A is 10 seconds and B is 5 seconds, then, for each emergency event moving into this process block, the range of possible delays will vary over the integers from 5 to 15 seconds, inclusive. The delay encountered by the event will be selected at random from this range of integers. If an emergency event enters decision point D1(P3.0) and decides to render active aid, it moves to subprocess P3.1 (Analyze/Render Aid). This subprocess involves a number of different actions that a citizen can take such as reducing the chances of further harm to the injured, administering first aid, sending a second person for additional assistance, assessing the emergency scene and going for help, and so on. Some studies have been conducted which include delay times and other insights into this process (see Appendix A and Bibliography). The average delay, however, should be carefully evaluated in each EMS area so that the best approximation is selected for specified times of the day, week, month, and season.

If personnel at the emergency scene decide that additional assistance is required, the emergency event moves to subprocess P3.3 (Decide Whom to Notify). The delay in this process depends on the assisting person's knowledge of the EMS system and familiarity with the political jurisdictions and their associated public safety systems. SRI International has conducted several surveys for clients which may provide assistance in developing data collection relevant to this subprocess. The next subprocess, P3.4 (Decide How to Notify) is closely related to P3.3 and involves the same data collection techniques.

If the person assisting decides not to request additional assistance, the emergency event enters subprocess P3.2 (Private Resources). This subprocess has not been fully defined because it is considered outside the scope of this telecommunications study; however, it must be represented because it changes the number of emergency events that subsequent processes of the model will not be required to serve. In addition, EMS system managers and planners need to understand why persons assisting in these emergency events elected not to use the public safety system.

4.3.5. Process P4.0: Citizen Emergency Access Process

This process provides the communications link between a citizen requesting aid and the public safety answering point (PSAP). Since the primary method of emergency citizen access is the public telephone system, the major emphasis of this subsection will be on that system.

Events entering P4.0 - Citizen Emergency Access, move into a cascade of decision points which are programmed for a local EMS area by setting the statistical transfer blocks D1(P4.0), D2(P4.0) and D3(P4.0) to reflect the level of actual traffic in each of the four methods illustrated in Figure 4-1. For example, if empirical data in a local EMS study revealed that 90% of the reports of emergencies entered via the public telephone system, the D1(P4.0) transfer block would be programmed to pass sequentially 90% of the events to P4.1 (Public Telephone System), and to transfer the remaining 10% to one or more of the other three methods via D2(P4.0) and D3(P4.0). It is possible that an emergency event may use more than one method to gain access finally to the appropriate agency; therefore, the sum of the four access methods may be greater than the events entering the citizen access system.

4.3.5.1. Process P4.1: Public telephone system process. Events moving into process P4.1 encounter a series of delays commencing with subprocess P4.1.1 (Locate Private/Public Telephone). The delay encountered in locating a telephone can be approximated through follow-up interviews, analysis of public telephone locations, and interviews with public safety call answerers.

If the emergency caller knows the emergency number or it is posted on the telephone, and the telephone requires no coins, the event moves into subprocess P4.1.7 (Dial Emergency Number). The delay in dialing depends on several factors; the number of digits (9-1-1, or some seven digit number), the anxiety of the caller, and whether the telephone is touch-tone or rotary dial. A stop watch can be used for measuring the approximate dialing delay in the local EMS service area.

After dialing the number, if an emergency telephone circuit is available, the event moves immediately through subprocess P4.1.8 (Capture Emergency Telephone Circuit) and into subprocess P4.1.9 (Emergency Telephone Ringdown). Ringdown is defined as the length of time that a telephone rings before it is answered. Given the normal telephone-company standard that each ring is two seconds long followed by a four second pause, a ten second ringdown time allows two rings. Some PSAP's have intercept equipment which is activated after some predetermined delay (e.g., 10 seconds) if the emergency call is not answered. The caller is advised that there is a delay and not to hang up. The delay encountered in this subprocess is dependent on the traffic design criteria in the next major process, P5.0 (Call Answering and Dispatch).

When the event was waiting and then moved into P4.18 (Capture Emergency Telephone Circuit), statistical data were being collected by a GPSS subroutine involving the queue of the event and the placement of the captured "telephone" circuit in a computer simulated storage facility. Some of the data generated by these GPSS subroutines include total calls processed during the simulated period, average length of time per call, average trunk utilization, and so on. These data factors will be presented and analyzed in Section 5.

If the emergency caller does not know the emergency telephone number and it is not posted on or near the telephone, the caller has the option of contacting the commercial telephone operator or looking up the emergency number in the telephone directory. The probability of the emergency caller's knowing the emergency number has been studied by a number of consulting firms, most notably SRI International. These studies involved citizen questionnaires and/or interviews to determine various constraints to citizen access. Determining probability figures for this decision point D1(P4.1.0) in a specific EMS area will be influenced by such factors as community size, the number and geographical definitions of adjacent political jurisdictions, the quantity and listing of emergency telephone numbers in the telephone directory, the effectiveness of EMS public education, the number of visitors and tourists in the community, and so on. If the caller decides to look up the number, the event moves into subprocess P4.1.5 (Look Up Emergency Number). The delay involved in looking up the emergency number can be locally approximated by experimentally testing a number of citizens to determine their delay in responding to some emergency scenario.

If the emergency caller elects to dial the operator and the telephone requires no coins, the event enters subprocess P4.1.2 (Dial "0" Operator). After the caller dials "0", the event enters subprocess P4.1.3 (Operator Delay). This process is somewhat over simplified because the telephone industry has dramatically changed its policy toward the role of the telephone operator. Factors such as direct distance dialing and 9-1-1 emergency numbers have changed telephone operator staffing patterns and physical locations so that far greater delays are now common in attempting to gain operator assistance to report emergency events. Delay for this process can be determined by calling the telephone operator at selected times of the day, week, and month to establish the mean and extreme delay times. This information is useful in a simulation model, and it is also valuable for EMS public education programs.

If coins are required in decision point D5(P4.1.0), the event moves into subprocess P4.16 (Locate Coins). The delay in this process involves the time to locate a coin in a purse, pocket or request change from a bystander. The literature reviewed during this study contained no research data on the probability of having the necessay coins in those cases involving emergencies. If the local EMS area public telephones require coins to gain a dial tone, experimental studies or probability theory can be employed to approximate the delay factor as simulated by the decision point in D6(P4.1.0). If coins are not located, the caller must seek a private telephone, leave the immediate area to find change or use a different citizen access method.

In decision point D7(P4.1.0), if the emergency caller receives a busy signal, the event is transferred to subprocess P4.1.11 (Busy/No Answer Delay). This delay involves the standard telephone switching time to receive a busy signal and terminate the call. For this simulation model the probability of receiving a busy signal (blocked call) on the emergency telephone service is .001 (Grade of Service P001).

In decision point D8(P4.1.0), if the wrong number is dialed or telephone switching errors cause an incorrect connection, the event moves into subprocess P4.1.0 (Check Emergency Telephone Number). While several studies implied that the anxiety of the emergency environment was conducive to errors in dialing, no research data was found that clarified or quantified the probability of such errors.

In decision point D9(P4.1.0), if the event is not answered in some predetermined period by the PSAP emergency call operator, the event is routed to subprocess P4.1.11 (Busy/No Answer Delay). For this simulation model the probability of the call being delayed beyond some predetermined time (e.g., 10 seconds) is .01 (Grade of Service P01).

4.3.5.2. Process P4.2: Land/mobile radio (LMR) system process. Events moving into process P4.2 encounter a number of decision points starting with D1(P4.2.0). If the emergency caller has a radio, and no radio relay is required, and a radio channel is available, the event moves to subprocess P4.2.4 (Send Radio Message). The delay involved in sending the message will depend on the emergency incident location, radio training, radio presence of the caller, and so on. If the radio message is received and acknowledged, the event moves to subprocess P4.2.6 (Consolidate Information). This process includes the time required for the radio call receiver to evaluate the information. Subprocess P4.2.7 (Contact Public Safety Agency) is the delay involved in determining the appropriate agency to notify and the method of notification. Delay estimates for these two processes require an understanding of the local LMR user organizations (i.e., business, industry, C.B., amateur, . . .) and the level of support they provide to the public safety agencies and the community in general.

Decision point D6(P4.2.0) assumes that if the emergency call receiver does not relay the emergency message to the PSAP via the public telephone system, a local LMR channel is available to contact directly the agency dispatcher.

If the emergency caller does not have an LMR unit, the event moves to subprocess P4.2.1 (Locate Radio). The delay encountered in this subprocess again is highly dependent on the conditions in the local EMS area. Studies conducted by Systems Applications, Incorporated (see Appendix A and Bibliography) evaluated various technologies (e.g. LMR-voice, LMR Beacon-precoded message, . . .) and provided some probability and delay approximations; however, additional research in this technology is needed to determine if LMR beacon technology is feasible. Subprocess P4.2.2 (Radio Relay Coordination) is also quite vague and must be analyzed at the local EMS level based on probable accident locations, availability of LMR repeaters, propagation characteristics of the area, and the coordination of business, C.B., and amateur radio organizations. Delay estimates for this relay process can be developed through experimental studies and discussions with local business, C.B., and amateur organizations.

If a radio channel is not immediately available for transmission of an emergency message, the event moves into subprocess P4.2.3 (Wait for Channel). The delay encountered in this subprocess is primarily a function of average message length, average number of message arrivals per unit time, and/or interference. Delay approximations for this process can be calculated or existing data can be evaluated using the analytical techniques discussed in Section 5.

If a radio message is not received in whole or part, the event moves into subprocess P4.2.5 (Repeat Message Coordination). This subprocess involves the time to determine what additional information is required and/or who sent the request for emergency assistance. Various types of man-made and/or environmental interference may contribute to the lost information. Local radio channel monitoring and radio user interviews will assist in establishing delay estimates for this process.

4.3.5.3. Process P4.3: Call box system. Events moving into process P4.3 encounter subprocess P4.3.1 (Locate Call Box). This delay block incorporates a number of different actions which involve remembering the location or looking for a call box. Delay estimates for this process can be calculated based on the number and location of such call boxes in the EMS service area. If a call box is located and it is operable, the event moves to subprocess P4.3.2 (Activate Call Box). The delay in activating the particular call box system(s) in an EMS area can be estimated through simple experimentation with the system. The call box message in the simulation model is assumed to terminate at some agency such as the highway patrol, highway maintenance, freeway authority for highway call boxes, and public safety agencies for fire, police and emergency medical call boxes.

4.3.5.4. Process P4.4: Direct contact process. This process involves a person's physically locating and reporting an emergency event directly to a public safety agency. This process was included as a means of citizen access because it is still used in some EMS areas. The process of events in P4.4 are common to most agency operations and the delays involved can be estimated with locally available information. The statistics generated by the GPSS subroutine can be analytically self-checked using basic queueing theory set forth in the Appendix A references or other available texts.

4.3.6. Process 5.0: Emergency Answering and Dispatch Process

The call answering and dispatch process involves a complex interrelated set of subprocesses whose primary responsibility is expediently to link an emergency need and an emergency response. There are four generally accepted configurations which define the emergency answering and dispatch processes: direct dispatch, call relay, call transfer, and call referral (see Section 3). The answering and dispatch process might use one or more of the four configurations in its initial, operational design and then be modified to accommodate changes in interagency policy and cooperation. As noted previously, this study has chosen not to develop direct dispatch for the reasons delineated in Section 3.

In the simulation model, the emergency events entering the P5.0 process (see Figure 4-2) are statistically apportioned between call relay, call transfer, and call referral by the program values assigned to decision points D2(P5.0) and D3(P5.0). Data collected from the EMS area can be used to determine the percentages assigned to each of the three configurations.

The subprocesses of the different configurations will now be analyzed using the Figure 4-2 flowchart.

4.3.6.1. Process P5.1: Direct dispatch process. As discussed in Section 3, the direct dispatch concept is not developed in this model. If a user has a one-stage direct-dispatch system, minor programming changes can be made to the P5.2-Call Relay Process to simulate satisfactorily the direct dispatch process.

4.3.6.2. <u>Process P5.2: Call relay process</u>. The call relay process in this demonstration assumes a two-stage configuration, employing emergency call operators and dispatchers. When the event moves into P5.2-Call Relay Process and an emergency-call operator is available, the event moves immediately through subprocess P5.2.1 (Capture an Operator) to subprocess P5.2.2 (Obtain Emergency Information). If an emergency-call operator is not available for service, the emergency caller is held in queue until an operator becomes available or the caller terminates the call. In the emergency environment, it is more likely that the emergency caller will wait until served, especially if a tape recording assures the caller that a call operator will be available in a few seconds. The telephone procedure in this model assumes that if the delay in answering the emergency caller exceeds approximately 10 seconds, the call is answered by an intercept device and a taped message asks the caller to stand by. While the emergency caller is waiting to be served (in queue), statistical delay data are collected by a GPSS subroutine. Analysis of these data will be presented in Section 5.

As noted, when the emergency-call operator is captured, the event moves into subprocess P5.2.2 (Obtain Emergency Information). This process involves the emergency caller's relating the key aspects of the emergency to the operator. The operator should be trained to probe with leading questions that capture the information with a minimum of delay. A study was conducted by G. B. Keller and R. R. Lanese (1977) that analyzed the role of the call-operator and that defined those message characteristics which influenced the operator's decision making process. Certain aspects of this study raise important questions regarding the role, responsibility, and training of the operator.

The delay contributed by the P5.2.2 subprocess can be empirically collected by monitoring recorded tapes and/or participant observation. The use of operator forms is generally not effective for quantifying this delay element because the devices (time stamps) used to record the time generally have a minimum time increment of 1 minute. In addition, there is no assurance that the operator will time stamp the report form to coincide exactly with the beginning or termination of an event. A number of data collection studies have been conducted for various call answering configurations and different demographic conditions. These studies are referenced in the bibliography and Appendix A.

Based on the information provided by the emergency caller and perhaps other related sources, the operator must determine the validity of the emergency request. If the operator determines that the request is valid, the event proceeds through decision point D1(P5.2.0) to subprocess P5.2.3 (Terminate Emergency Call). In some cases, the call-operator may temporarily place the emergency caller on hold, with the intent of collecting additional emergency-scene information. The model, as programmed, does not make provisions for this feature. When the emergency telephone call is terminated, the telephone circuit is removed from storage and is available to serve another emergency caller. The time delay in terminating the emergency call may be quite short and involve only hardware termination delays or may include some additional instructions from the operator to the emergency caller. Data collection for this subprocess is frequently included in subprocess P5.2.2 (Obtain Emergency Information). In practice, the user of this model may elect to consolidate those two subprocesses into P5.2.2 and may program P5.2.3 with a zero delay.

After the emergency call is terminated, the operator consolidates the emergency information as represented by subprocess P5.2.4 (Consolidate Information). This subprocess might include completing a form and/or determining the proper jurisdiction and responsible agency. If the operator determines that no additional critical information is required, the event proceeds through decision point D2(P5.2.0) and moves to subprocess D5.2.5 (Capture a Dispatcher). There are a number of different methods for conveying the emergency information to the dispatcher. If the information is transmitted electronically via telephone or computer terminal, some type of signaling alerts the dispatcher regarding an emergency service request. If the information is manually relayed via a conveyor belt system, pneumatic tube, messenger, or the like, a visual cue generally alerts the dispatcher of a service request. If a dispatcher is not available for service, the event must remain in queue until a dispatcher is released from storage. As before, queue and storage statistics are collected by GPSS subroutines. The delay involved in the electronic transfer of emergency information in this subprocess can usually be estimated from recorders and/or participant observation; however, data collection is somewhat more complicated for manual information transfer methods.

Once a dispatcher is captured, the event moves to subprocess P5.2.6 (Relay Information to Dispatcher). In this demonstration model, it is assumed that the information transfer is performed by some electronic means and the operator is not released until the dispatcher has acknowledged receipt of information on the emergency event. At that point, the operator is released from storage and is made available for the next emergency call.

Dispatcher subprocesses P5.2.7 (Review Emergency Information) and P5.2.8 (Determine Emergency Location) are interrelated, but P5.2.8 may require the dispatcher to employ visual aids or some other technology such as computer aided dispatch. If the necessary emergency information required for dispatching is received from the call operator, the event proceeds through decision point D3(P5.2.0) and into subprocess P5.2.9 (Type/Availability of Medical Units). At this point, the dispatcher determines the appropriate and available medical and other resouces that should respond to the emergency scene. The average delay assigned to this subprocess will normally be a continuation of subprocess P5.2.8 and sometimes will be difficult to differentiate; however, since P5.2.7 and P5.2.8 are functionally different subprocesses, they are treated individually in this demonstration model.

If the emergency medical resources are dispatched via land/mobile radio (LMR), the event proceeds through decision point D4(P5.2.0) and into subprocesses P5.2.10 (Capture a Radio Dispatch Channel).

If a radio dispatch channel is available, the event moves immediately to subprocess P5.2.11 (Transmit Medical Unit Call Sign). As before, statistics are generated by GPSS subroutines for channel delay, channel utilization and average channel usage.

If the medical unit receives the transmission from the dispatcher, the event moves through decision point D5(P5.2.0) and into subprocess P5.2.12 (Medical Unit Radio Reply). A simplifying assumption in this subprocess is that since the dispatcher has already captured a dispatch channel, then channel discipline assures its availability for the medical units' acknowledgement reply. Channel discipline, propagation characteristics, and other factors may not allow this assumption in some EMS areas. After the medical unit acknowledgement has occurred, the event moves to subprocess P5.2.14 (Send Dispatch Message). If the dispatch message is received by the medical unit, the event proceeds through decision point D6(P5.2.0) to subprocess P5.2.15 (Medical Unit Acknowledges Message). The delay for these LMR dispatch subprocesses can be collected from dispatch center recorders, from real time monitoring of the dispatch channels, or possibly from computer-aided dispatch statistics. As noted previously, dispatch records are generally not adequate for detailed analysis because the smallest time increment recorded is generally 1 minute.

After the medical unit acknowledges the dispatch message, the dispatcher assigns a medical control channel to the medical unit for LMR communications with the appropriate medical facility. Technically this subprocess is not a delay element at this point because it does not inhibit the movement of the medical unit to the emergency scene, however, a failure to establish coordination with the assigned medical facility can create medical control delays when the medical unit reaches the emergency scene.

The P5.2 subprocesses presented thus far have assumed a sequential, nontransfer flow through the decision points. These same decision points will now be analyzed to determine what occurs when the events are statistically transferred to the alternative subprocesses.

In decision point D1(P5.2.0), if the call operator determines that an emergency medical response is not appropriate, but a non-medical response (law enforcement, fire, search and rescue, . . .) is required, then the event moves to subprocess P5.2.17 (Operator Coordinate Other Response). This subprocess simulates the delay involved for the operator to coordinate the nonmedical response. A review of the operator records and recorder tapes should provide estimates for the percentage of nonmedical calls and information on operator service delay.

In decision points D2(P5.2.0) and D3(P5.2.0), if additional information is required by the call operator or dispatcher the event proceeds to subprocess P5.2.13 or subprocess P5.2.16 respectively. These call-backs are required if critical information is needed before resources can be dispatched.

In decision point D4(P5.2.0), if some configuration of telephone dispatch is employed, the event proceeds to subprocess P5.2.19 (Telephone the Medical Unit Station). This subprocess may involve automatic ringdown, intercom, public telephone "all call" or some other configuration. The delay time in contacting the station or possibly volunteers can be estimated by observing the system operation or monitoring the logging recorder tapes. If the telephone dispatch is answered, the event moves through decision point D8(P5.2.0) to subprocesses P5.2.20 (Relate Dispatch Message), P5.2.21 (Acknowledge Message Received) and P5.2.22 (Medical Unit Clear the Station). Delay data for these subprocesses would require on-site data collection and interviews with the medical unit personnel involved.

In decision point D6(P5.2.0), if the medical unit fails to receive the message, the event proceeds to subprocess P5.2.30 (Repeat Message Coordination). This process includes requesting the dispatcher to repeat the message or those parts which were distorted.

There are a number of instances when field units and other agencies will contact the dispatcher via an LMR channel. Subprocesses P5.2.24 (Capture a Radio Dispatch Channel) through P5.2.29 (Dispatcher Evaluate Resource Priorities) are designed to provide this LMR access to the dispatcher. The details of these subprocess blocks are similar to those already discussed, so further iteration is not necessary.

4.3.6.3. Process P5.3: Call-transfer process. In the call transfer process, the emergency call is transferred (switched) electronically to the appropriate agency rather than just the information being relayed as in P5.2-Call Relay Process. It is quite common in most call transfer systems for the operator to monitor the switching process to insure that the transfer to the second agency has been satisfactory. The emergency caller then repeats the emergency incident to the call operator in the second agency. The call answering and dispatch system of the agency receiving the transfer could be similar to P5.2 - Call Relay Process.

Events entering subprocess P5.3.1 (Capture an Operator) wait in queue unless an emergency call operator is available, and then the event moves immediately to subprocess P5.3.2 (Obtain Basic Transfer Information). The objective of this subprocess is to determine the type and location of the emergency (e.g., fire, vandalism, . . .) so that the emergency call can be expediently transferred to the appropriate agency. When this basic emergency information is received by the call operator, the event proceeds to subprocess P5.3.3 (Transfer Caller to Appropriate Agency). If the emergency call is satisfactorily transferred to the appropriate agency, the event moves through decision point D1(P5.3.0) and is terminated as far as the transferring agency is concerned. If the transfer is not satisfactory, the operator continues until the transfer is complete. In order for the call transfer process to replicate the system more closely, the emergency telephone circuit is not released from storage for approximately 60 seconds after transfer, to simulate the receiving agency's call answering process. In the call transfer process the telephone circuit of the transferring agency remains in service (storage) until the receiving agency terminates the call.

4.3.6.4. Process 5.4: Call referral process. This process is intended for those events which may be perceived as emergencies by the caller, but do not require a public safety response. Depending on call referral answering policy, the call operator might suggest alternatives for the caller or in some instances provide a telephone number for the caller to contact.

When the event enters P5.4 - Call Referral Process, it proceeds to subprocess P5.4.1 (Capture an Operator). If a call operator is available, the event immediately moves to subprocess P5.9.2 (Obtain Basic Referral Information). This subprocess probes for the primary problem and moves to subprocess P5.4.3 (Provide Information to caller) when sufficient information is available. The operator then terminates the call and the caller must redial the referral agency.

4.3.7. Process P6.0: Emergency Medical Unit Transit Process

This process involves the movement of medical units from a stationary location (ambulance garage, fire station. . .) or non-stationary location (returning from call, enroute to a non-emergency transfer, coffee stop, . . .) to the emergency scene. A number of studies have been conducted regarding optimum location and number of medical units required to service an EMS area. Of particular note is a text by Edward J. Beltrami (1977) which not only directly addresses the problem of medical unit location, but demonstrates a number of important analytical techniques regarding travel time approximations and optimum medical unit station locations.

R. B. Andrews, et al. (1975) documented an analytic method referred to as Computerized Ambulance Location Logic (CALL). These and other references appear in the Bibliography and Appendix A.

In this demonstration model it is assumed that:

- o All medical units can be dispatched to any emergency medical incident in the EMS area.
- o Medical Unit dispatch policy selects the closest unit in terms of estimated travel time to the emergency scene.

The emergency event enters P6.0 and proceeds to subprocess P6.1 (Medical Unit Enroute). This subprocess accounts for the delay involved in determining the general location of the emergency, entering the flow of vehicular traffic and so on. Data collection for this delay generally requires on-site observations and interviews with medical unit personnel.

In decision point D1(P6.0), if the medical unit does not experience abnormal en-route delay to the emergency, it moves to decision point D2(P6.0). The event then proceeds through this decision point unless medical unit mechanical failure is experienced. Such failure in this demonstration model places the medical unit out of service for the remainder of the simulation run. If mechanical failure is not experienced, the event moves to subprocess P6.3 (Medical Unit Travel Time). This subprocess delays the medical unit by the length of time it would normally require to drive from the point of dispatch to the emergency scene. A nonuniform distribution has been assigned to this subprocess which randomly selects a different delay for each medical unit response, thereby simulating different distances to the emergency scene.

In decision point D3(P6.0), if traffic and/or crowds at the emergency scene are under control, the medical unit moves to subprocess P6.5 (Medical Unit Initial Scene Evaluation). This subprocess includes positioning the medical unit, surveying the scene, and determining if additional assistance is required.

In decision point D1(P6.0), if en-route delay is experienced beyond the normal travel delay of subprocess P6.3, the event moves to subprocess P6.2 (Abnormal Travel Delay). This subprocess accounts for traffic congestion, inclement weather, incorrect address, and so on.

4.3.8. Decision Point D2: Additional Service/Equipment Required?

Events moving into this block, proceed sequentially if additional service and/or equipment are not required or if medical unit personnel can perform their functions without the outside assistance. Emergency scene services such as clean-up crews, utility company personnel, wrecker crews, and so on, which may be required but do not delay the medical unit process, are not included in deriving the statistical transfer percentage for this decision point.

If outside assistance is required, the event is transferred to P7.0 -Service Unit process.

4.3.9. Process P7.0: Service Unit Dispatch and Transit Process

Within this demonstration model, this process is only activated when the requested services and/or equipment (i.e., law enforcement, fire, search and rescue, . . .) are required before the medical unit personnel can proceed with patient care and transfer to a medical facility.

The various subprocesses included in P7.0 will not be individually discussed because of their similarity to previously treated blocks in other processes. In this model it is assumed that the various service units are dispatched via land/mobile radio (LMR).

4.3.10. Decision Point D3: Advanced Life Support Available?

EMS areas with no advanced life support would program this decision point so that no events would be transferred to P9.0 - Advanced Life Support. Those EMS service areas with both basic and advanced life support would set the transfer percentage to P9.0 - Advanced Life Support, based on a review of dispatch, ambulance and hospital records.

4.3.11. Process P8.0: Basic Life Support (BLS) Process

The BLS process will not be analyzed because it is nearly identical to process P9.0 - Advanced Life Support, which will be treated in the next subsection.

4.3.12. Process P9.0: Advanced Life Support (ALS) Process

In the simulation of ALS, one of the critical delay factors which can be mitigated in this process is the transit delay to the medical facility. If ALS procedures can stabilize the patient's condition at the emergency scene or enroute to a medical facility, the effects of the transit delay can be reduced.

Two key factors which enable physicians to extend their expertise to field emergency medical personnel are standardized training and LMR communications. There has been some debate over the effectiveness of using installed LMR medical systems; however, the actual use may be less important than the fact that it is available if the physician or medical unit personnel need it. Also the availability of LMR communications appeases some of the legal questions concerning delegation of physician responsibilities to trained technicians.

Events entering process P9.0 proceed to subprocess P9.1 (Patient Triage). This subprocess involves assessing the condition of the patient and determining the course of action to be taken. The latitude that the medical unit personnel have in this process must be evaluated on the basis of local protocols, state laws, and federal guidelines. If the decision is made to transport the patient, and medical direction and control has been established, the event proceeds through decision points D1(P9.0) and D2(P9.0) to subprocess P9.3 (Start Advanced Life Support). At this point, medical unit personnel commence those advanced life support procedures authorized by standing orders or protocols. Subprocesses P9.4 (Advise Medical Control of Patient Condition) and P9.5 (Medical Control Direction) involves direct communications with the medical control facility via LMR. The LMR medical channels in this simulation model are dynamically assigned to the medical unit and medical control facility by the dispatcher. Because of the highly critical nature of the conversations and/or telemetry over the medical control channels, a high-grade voice link is required.

In subprocess P9.6 (Transfer Patient to Medical Unit), the patient is moved to the medical unit in preparation for transport to a medical facility. The order and details of subprocesses P9.3 through P9.6 will vary from patient to patient and also between EMS area protocols. In some cases the patient may be transferred to the medical unit immediately and then advanced life support may be initiated. In other cases the patient may be stabilized before being transferred to the medical unit. As noted previously, the EMS managers and planners are encouraged to modify the model so that it more closely replicates their local EMS system.

After the patient is transferred to the medical unit, the event proceeds to subprocess P9.7 (Medical Unit Clear the Scene). This subprocess accounts for the delay in clearing the traffic and/or crowds at the emergency scene and the delay entering the flow of street traffic. If abnormal transit delays are not encountered, the event proceeds through decision point D2(P9.0) to subprocess P9.9 (Medical Unit Travel Time). As noted in P6.0 - Medical Unit Transit Process, medical unit travel time is the normal delay encountered in driving from the emergency scene to the medical facility. If the medical unit does not experience mechanical failure and the medical facility is alerted to the medical unit arrival, the event moves through decision points D4(P9.0) and D5(P9.0) to subprocess P9.11 (Off-load Patient From Medical Unit). This subprocess involves removing the patient from the medical unit and onto the medical facility transport device. In subprocess P9.12 (Medical Facility Delay), the medical facility personnel move the patient into the emergency room.

In decision point D1(P9.0), if the medical unit personnel and/or involved citizens determine that transport is not necessary, the event moves to subprocess P9.2 (Units Clear the Scene). In decision point D2(P9.0), if medical control is not available through LMR communications or standing orders the ALS process becomes a basic life support process for that particular medical unit event. This transfer may occur if the LMR communications system fails because of hardware and/or interference problems and advanced life support cannot proceed without the medical communications channel.

In decision point D5(P9.0), if the receiving medical facility has not been advised that a medical unit is in transit to that facility, the event proceeds to subprocess P9.10 (Medical Facility Preparation Delay). This delay is generally not a problem when the medical facility providing the medical direction and control is also the receiving facility; however, if the medical unit is proceeding to another medical facility and they are not advised, some delay may occur.

The techniques involved in collecting data for the subprocesses in P9.0, requires a thorough understanding of the local EMS system and direct observation of the subprocesses. If tape recorders monitor the LMR medical control channels, traffic and interference data can be captured from that source, otherwise, real-time transmission must be monitored.

5. ANALYSIS OF THE EMS TELECOMMUNICATION SIMULATION

This chapter will review how the model was verified and validated. During this review, certain data collection and analysis problems will be discussed. Selected simulation run output data have been summarized in tables for certain variables which relate to telecommunications planning. Other data related to transportation were not included because these were beyond the scope of this study.

5.1. Model Verification

The verification stage of simulation model development is concerned with determining whether or not the model is properly programmed. Verification of the model's programmed structure requires manipulation of its random seeds and subroutines so that known input-output relationships can be examined and verified. The verification stage is not composed of comparisons of the model's responses with known measurements, or recordings of the modeled system, as this is defined as validation (Mihram, 1972). Verification is concerned with the internal consistency and logic of the programmed model. It is directed toward establishing whether or not the logical structure of the model is compatible with the user's intentions.

The model was initially programmed into the nine processes (P1.0-P9.0) discussed in the previous two chapters. Each process was then tested using elementary, deterministic values to verify that the logic of the system was operating as designed. Model input and output were evaluated to insure that the decision points and subprocess delay blocks were functioning as programmed. Once deterministic verification had been accomplished by suppressing all randomness in the stochastic model, other verification tests were conducted by partially suppressing stochasticity. This same process was repeated as the various nine processes were joined together into an EMS systems model.

The next step in verification was the introduction of selected probability distributions and random number seeds. Different random-number generators were employed to improve the independence of the random seeds. Simulation runs were then conducted to determine if the resulting random variables exhibited the designed distribution properties. A series of 30, separate simulations were run and then analyzed. The numerical values that were programmed into the decision points and subprocess delay blocks for these runs are set forth in Appendices A and B. The random-number generator values for each of the 30 simulation runs are set forth in Table 5-1. The simulation runs were executed in three groups of ten. The resulting EMS system response-time curves are plotted in Figure 5-1. As noted in Figure 5-1, the three sets of simulation runs using the random seeds in Table 5-1 are very similar. Table 5-2 shows the average 24-hour arrival rate and mean service rate (μ) for each of the 30 runs. In addition, the mean ($\bar{x}$), variance (s^2) and standard deviation (s) have been calculated for the 30 simulation runs. These runs were not initially analyzed for the effects of initial bias because the verification stage was primarily concerned with internal model consistency. Initial bias

CONTINUED

1 OF 3

Table 5-1. Random Number Assignment for Simulation Runs

Simulation Run Number	Random Number Generator Seed			
	RN1	RN2	RN3	RN4
1	511	39	7	663
2	741	211	483	659
3	111	157	539	211
4	26	572	265	49
5	417	111	197	363
6	273	921	274	622
7	967	712	571	923
8	433	412	379	628
9	695	219	773	61
10	344	37	871	29
11	287	51	123	35
12	873	110	273	91
13	151	618	183	274
14	228	734	592	36
15	57	317	74	127
16	483	213	916	376
17	68	447	327	21
18	764	87	391	57
19	356	998	27	692
20	22	260	563	38
21	538	45	387	933
22	175	439	413	117
23	845	257	628	291
24	569	347	168	416
25	916	471	583	182
26	651	493	719	581
27	185	659	359	476
28	362	491	753	188
29	683	248	157	549
30	412	539	825	462

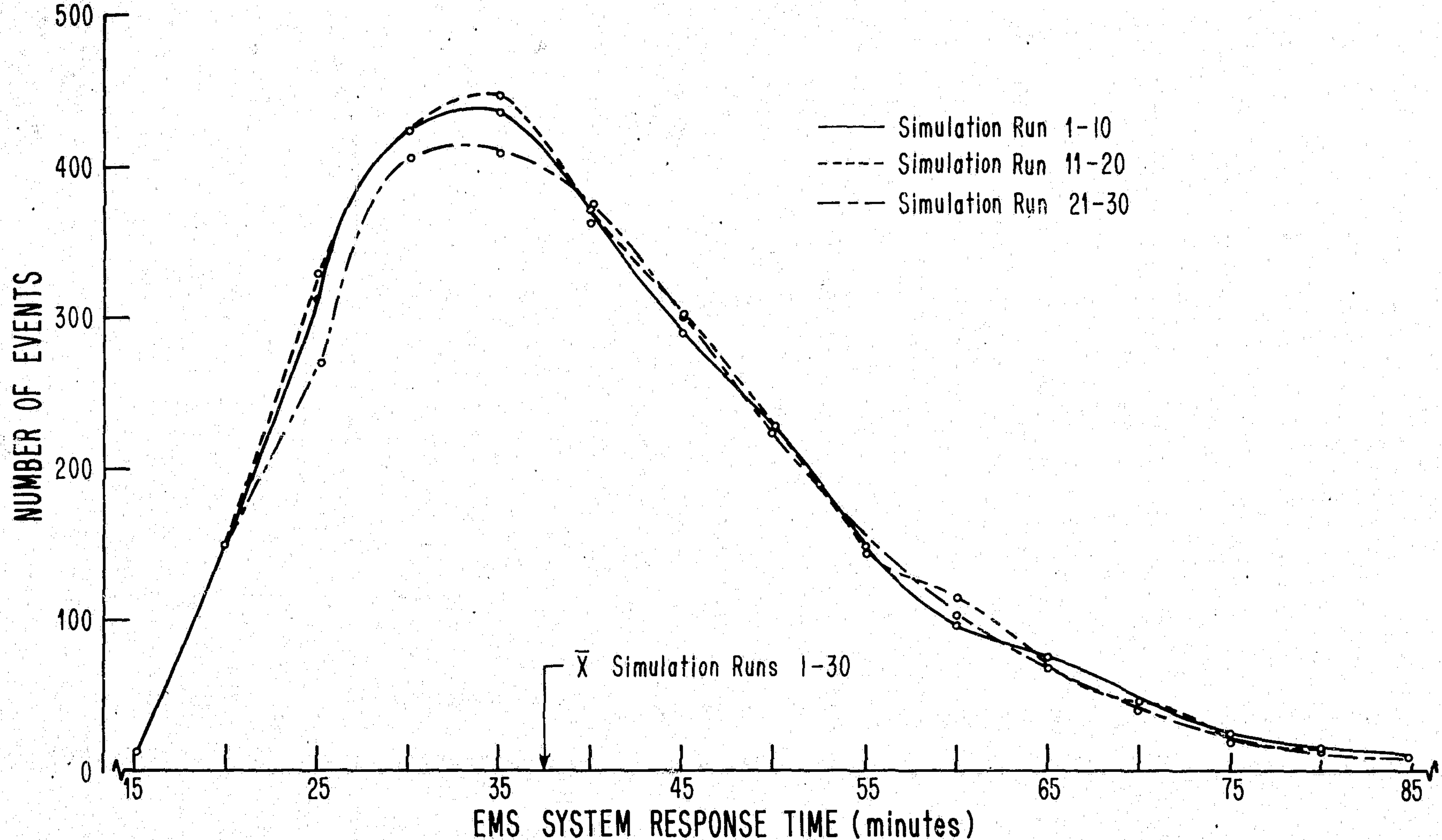


Figure 5-1. EMS system response time distribution.

Table 5-2. EMS System Response Time Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	(Not Used)
1	274	2239	
2	254	2213	
3	247	2668	
4	258	2292	
5	282	2132	
6	242	2223	
7	262	2239	
8	296	2148	
9	294	2304	
10	280	2119	
11	294	2169	
12	288	2341	
13	249	2204	
14	253	2075	
15	245	2255	
16	266	2407	
17	279	2183	
18	264	2281	
19	270	2290	
20	274	2138	
21	251	2574	
22	222	2270	
23	290	2129	
24	262	2232	
25	258	2229	
26	284	2161	
27	257	2253	
28	284	2303	
29	253	2110	
30	262	2303	
Total Events	7994	–	
Mean ($\bar{x}$)	267	2250	
Variance (s^2)	317	15,634	
STD. DEV. (s)	18.1	127.2	

effects on simulation model design considerations are discussed later in this subsection.

From the data in Table 5-2, a confidence interval was calculated using equation (5.1). For this study, a .99 confidence interval was assumed.

$$.99 \text{ C.I.} = \bar{\chi} \pm t s_{\bar{\chi}} \tag{5.1}$$

where,

$\bar{\chi}$	=	Sample mean
t	=	The number of standard errors of the mean ($s_{\bar{\chi}}$) which must be added and subtracted from χ
$s_{\bar{\chi}}$	=	Standard error of the mean $s_{\bar{\chi}} = \frac{s}{\sqrt{n}}$

Using the values of Table 5-2 and equation (5.1), the following confidence limit was derived:

$$.99 \text{ C.I} = 37.5 \text{ minutes} \pm (2.76)(.39)$$

$$= 37.5 \pm 1.1 \text{ minutes.}$$

This confidence interval serves only as an approximation because the curve represented in Figure 5-1 departs from a normal distribution. It should also be noted that Figure 5-1 and Table 5-2 represent those EMS events which moved through the entire EMS system. Other events were transferred from the model and terminated by various subroutines as discussed in Section 4.

The next verification element checked was the model's sensitivity to changes in the following variables:

- Subprocess delay variables
- Decision point variables
- Server variables (i.e., number of telephone circuits, dispatchers, . . .)

The delay and decision point variables were verified during model programming. One area which might be perceived as an inconsistency is the dramatic difference in the assignment of subprocess delay values. For example, one subprocess block may be assigned 7 seconds and another 360 seconds. It could be argued that the 7-second block has no real significance in simulation outcome. The factoring of the processes into subprocesses and the assignment of numerical values has many benefits, some quantitative, some analytical and others economic. One of the purposes of this model is to encourage EMS managers and planners to weigh these differences and focus on those subprocesses which are locally defined as priorities from an EMS systems perspective; therefore, these delay differences are considered an important aspect of the modeling process.

The sensitivity of the model with respect to changes in the number of servers is treated in the next subsection of this chapter.

The last verification category checked was initial bias. The problem of initial bias in simulation modeling results from starting a simulation run with the system in an idle state. Several techniques are available which can reduce the effects of initial bias. One technique is to use a longer simulation run which has the effect of reducing initial bias by averaging that effect over a larger sample period. Another technique is to start the simulation run with some prespecified load which closely replicates the actual system for the time period under analysis.

For this study, simulation runs 1 through 30 were executed assuming an idle system (see Figure 5-1). For the purpose of this verification step, it was not necessary to consider initial bias. These runs simulated a 24-hour period with a mean interarrival event time of 180 seconds (3 minutes), exponentially distributed. This simulation period was designed to be divided by 24 to select a mean value for the peak hour. It was hypothesized that by averaging the peak over a 24-hour period the initial bias and other spurious effects would be averaged out. In addition, this longer sample period allowed for a larger number of emergency events to be introduced into the model, assuring a more representive distribution in the transfer and subprocess delay blocks.

To determine if the 24-hour sample did reduce the effects of initial bias, an additional set of ten simulations (31 through 40) was executed with full load start-up. In addition, the random-number seeds of simulation runs 11 through 20 were used so that a comparison could be made between these two sets. The data plots from these runs are shown in Figure 5-2. Simulation runs 11 through 20 are also plotted to provide a comparison. The means for simulation runs 1 through 30, 11 through 20, and 31 through 40 are also included to show the close relationship which exists between these three sets of data. From the data, little effect of initial bias is noted.

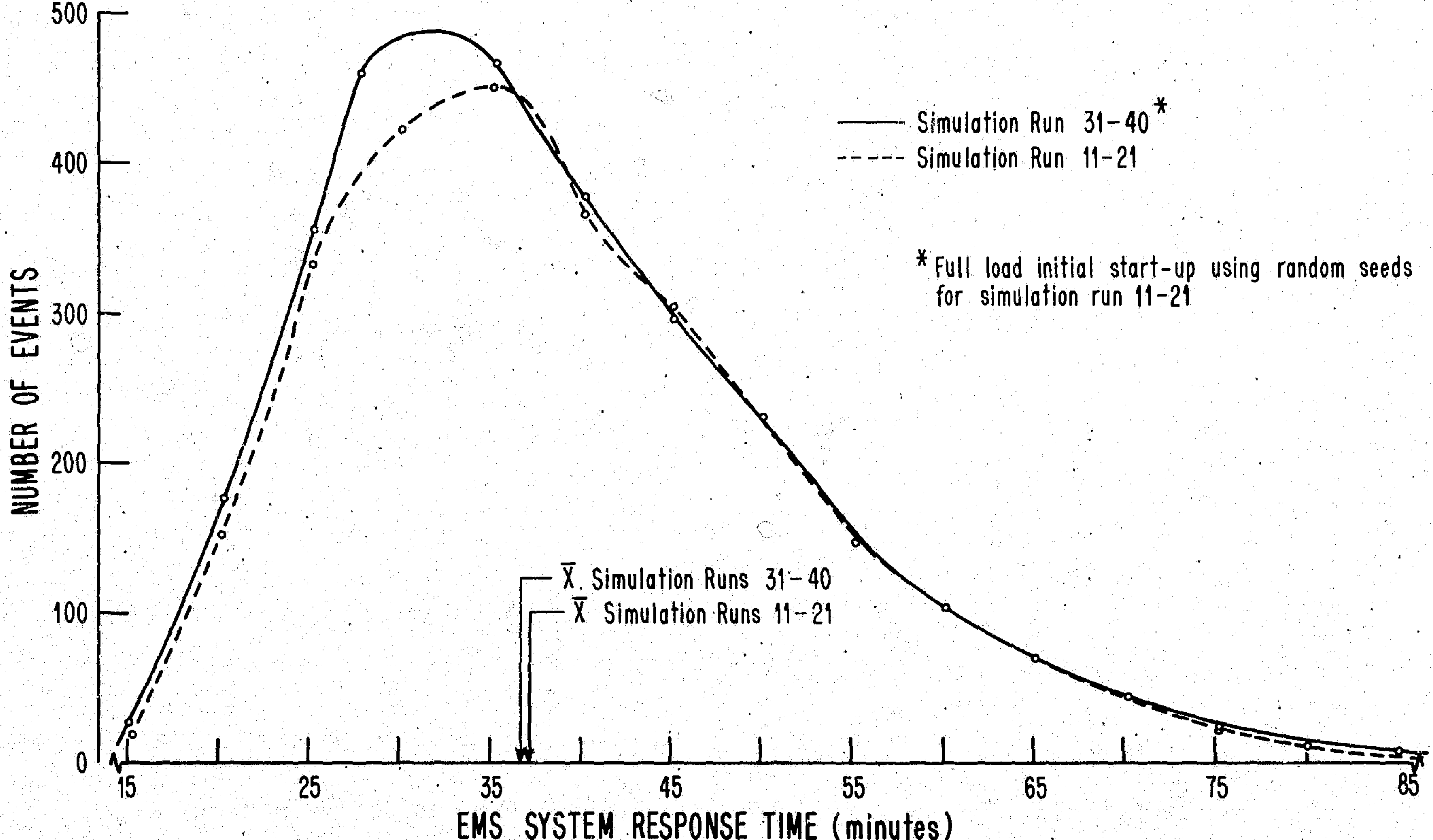


Figure 5-2. EMS system response time distribution.

5.2. Validation of the Model

Model validation is concerned with comparing the model's response with that of the modeled system. This assumes that the conditions producing both responses are essentially the same. Both the independently seeded stochastic simulation model and the modeled system produce random variables necessitating the use of statistical procedures for comparing responses (Mihram, 1972). This study will employ analytical equations to test the validity of the simulation model equations which are known to represent certain empirical phenomena. What is proposed, is validation of the model by comparing the queue and storage simulation data with traffic approximations obtained from theory.

The only readily available analytical results in the multi-server cases are for Poisson arrivals and exponential service times (Anderson, 1973). The most likely candidate for the emergency medical environment seems to be the Erlang C equation which applies under the following assumptions:

- o Exponential Holding Time
- o Lost calls delayed
- o Calls served in order of arrival.

The primary parameters of interest in this analysis are as follows:

λ = mean arrival rate per unit time (i.e., per hour)

μ = mean service rate (i.e. 50 seconds per event)

P(>0)= probability of delay greater than zero

The assumptions of Erlang C and its potential in solving for the percentage of calls delayed, makes it an important analytical tool for validating EMS systems models. The Erlang C equation and its various derivations are not included in this study since it has received close attention in numerous queueing and traffic theory texts. In order better to serve the EMS manager and planner, traffic loading graphs have been included as Figures 5-3 and 5-4. Figure 5-3 is for traffic loads in Erlangs from 0 to 1 and Figure 5-4 is for Erlang loads from 1 to 8. These figures serve as useful approximations for Erlang C traffic calculations. For other equations and larger load factors, a short traffic handbook written by T. Frankel (1976) provides a good reference manual for server system design and analysis.

5.2.1. Emergency Telephone Circuit Analysis

In analyzing the emergency telephone circuit requirements the three parameters noted above allow an analytical approximation of the probability of delay. Table 5-3 was developed from the data collected by the GPSS statistical subroutines. The four columns in Table 5-3 will be briefly discussed here.

Column 1 This column indicates the simulation run number using the random number seeds as listed in Table 5-1 and the

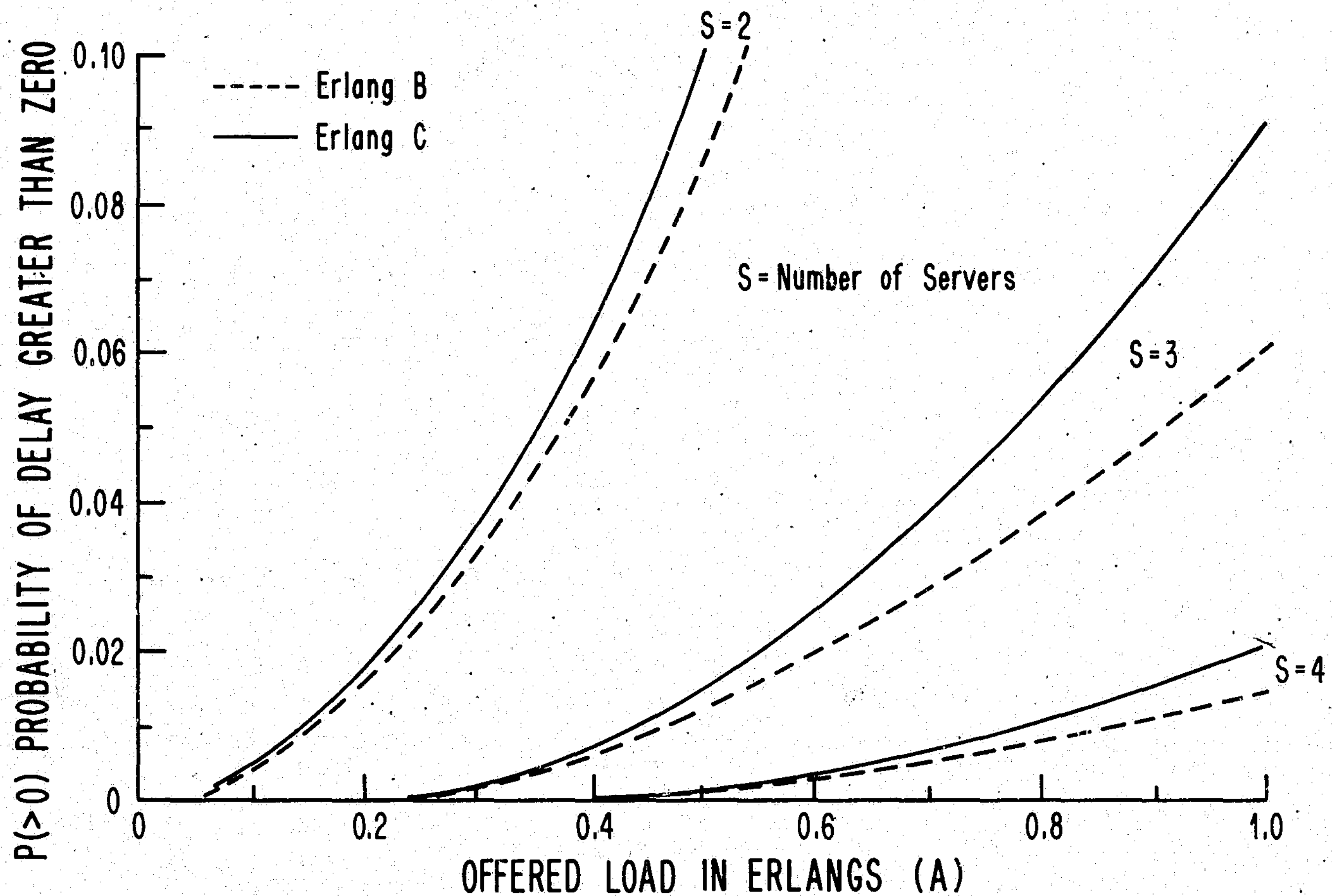


Figure 5-3. Erlang B and C equations as a function of Erlang (A) load.

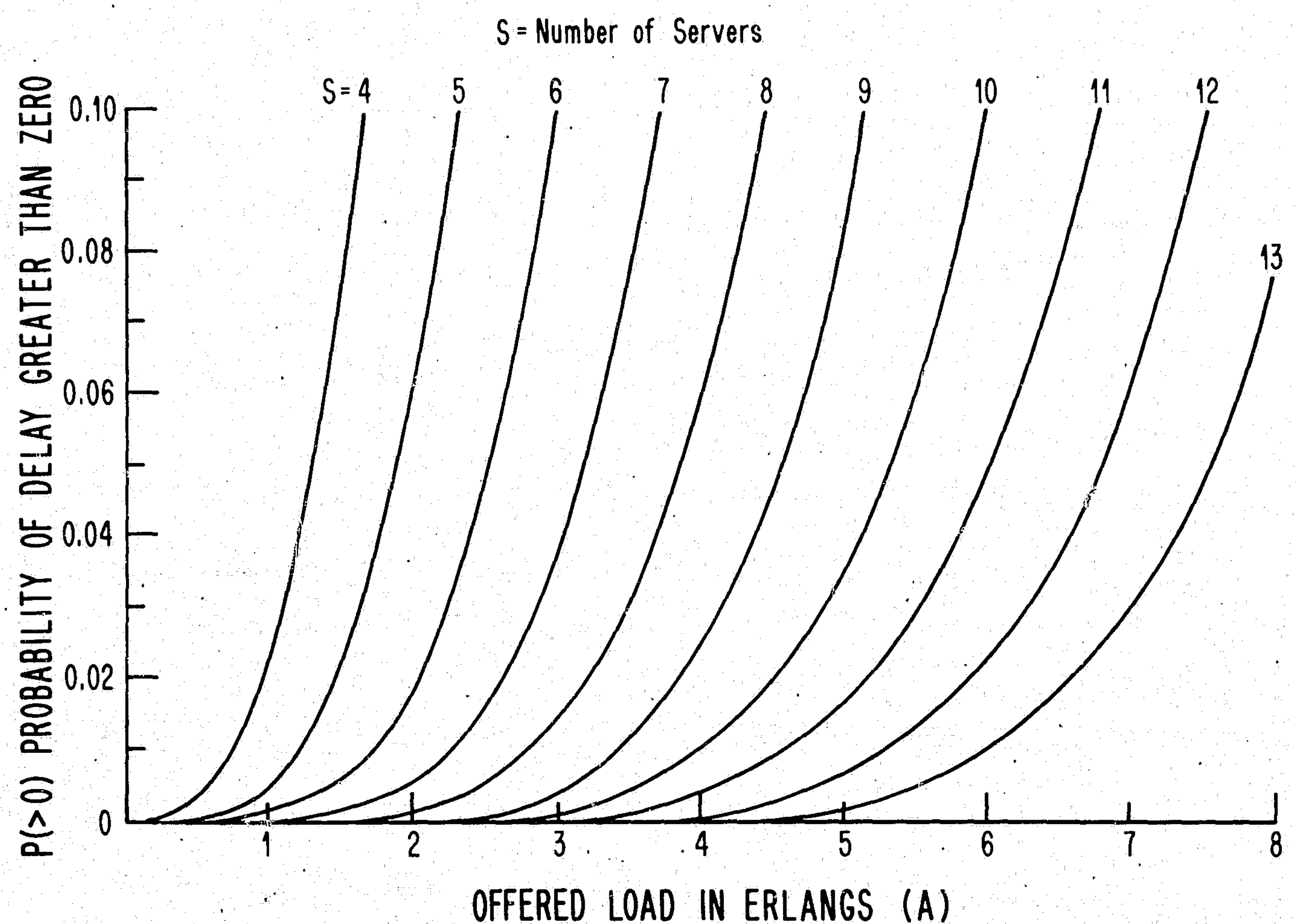


Figure 5-4. Erlang C equations as a function of Erlang (A) load.

Table 5-3. Telephone Circuit Traffic Data

1	2	3	4
Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation P(>0)
1	448	54	1
2	392	74	11
3	417	101	17
4	426	54	0
5	437	54	2
6	405	55	2
7	416	52	0
8	461	52	3
9	439	54	3
10	474	52	1
11	458	54	0
12	468	54	6
13	410	53	0
14	419	55	5
15	394	53	0
16	421	75	8
17	423	53	1
18	420	54	3
19	433	54	1
20	424	52	0
21	398	124	28
22	375	55	0
23	452	52	1
24	414	53	1
25	424	54	2
26	468	54	0
27	415	55	1
28	442	53	1
29	418	55	1
30	409	55	2
Total Events	12,800	-	99
Mean ($\bar{x}$)	427	59	
Variance (s^2)	567	241	
STD. DEV. (s)	24	16	
Mean Arrival Rate (λ) Per Hour	17.79	-	

Note: Three servers (telephone circuits) were used in these simulation runs.

computer program values set forth in Appendices A and B.

Column 2 This column shows the number of events which were served and/or held in queue during a particular simulation run. For example, in run number 1, a total of 448 events were served and/or held in queue.

Column 3 This column reflects the mean length of time in seconds that the number of events in column 1 were held in service. This mean length includes ringing, exchange of information and termination delays. In run number 1, the mean service rate was 54 seconds.

Column 4 This column reflects the number of calls in a 24-hour period that encountered a delay greater than zero. In run number 1, one call was delayed longer than zero seconds during the 24-hour simulation.

In practice, the probability of waiting for a time period greater than zero is more frequently used than zero. This factor is referred to as the probability of delay beyond some specified time and is denoted by P(>t). This P(>t) can be easily computed for various values of "t" if P(>0) is known. In this study only the P(>0) will be used with the understanding that the user may define locally acceptable service delay times.

At the bottom of the columns in Table 5-3, statistics have been included that will be used later in this subsection for analytical calculations. As noted, the analytical equation which will be used to analyze the emergency telephone circuit requirements is Erlang C. This equation was considered most appropriate, because in Section 4 it was assumed that an intercept recording prevented emergency callers from receiving a busy signal. This technique provides for delaying rather than blocking emergency calls. If a PSAP does not use this intercept technique, then the Erlang B equation and its attendant assumptions would probably be more appropriate. Figure 5-3 includes both Erlang B and C delay probability curves.

From the data in Table 5-3, the emergency telephone traffic load is computed using the following (5.2) equation.

$$\text{Erlang (A)} = \frac{\lambda\mu}{3600} \tag{5.2}$$

where,

λ = mean arrival rate per hour

μ = mean service rate in seconds.

Taking the mean arrival rate per hour (λ) and the mean service rate (μ) from Table 5-3, an Erlang (A) traffic load of .292 is calculated using equation (5.2). Using the graph in Figure 5-2, for three servers, a .37% analytical solution for P(>0) is calculated.

The next step involves determining P(>0) directly from the simulation model. In Table 5-3, the total number of events from the 30 simulation runs (12,800) is divided into the total number of events where the probability of delay was greater than zero (99). The resulting P(>0) is calculated to be .77%. This represents a net difference of only .4%, an acceptable approximation. These results are summarized in Table 5-4. As a practical matter, telephone circuit requirements for emergency systems are often overdesigned by choice or by telephone company policy (i.e., minimum of two 9-1-1 trunks are usually required from each exchange). While the user may choose to overdesign for operational and/or reliability reasons, the same data and analysis should be used to reach that choice.

5.2.2. Emergency Operator and Dispatcher Staffing Analysis

Estimating the appropriate staffing levels for PSAP's and dispatching centers is an important operational and economic task. Of central importance in determining the appropriate number of servers (call answers or dispatchers) is the total processing time required to service one call. The call processing time includes the time required to transfer emergency information from the caller, in addition to time required for record keeping and other coordination related to the emergency event. Estimating call processing time is more involved than telephone circuit analysis because the start and stop points of the various subprocess activities are less clearly defined.

Operational policies (i.e., local, state, and federal) also influence staffing levels by setting or recommending probability of delay standards for system performance. Behavioral aspects also

Table 5-4. Simulation and Analytical Comparisons for Server Subsystems.

SERVER SUBSYSTEM	SIMULATION P(>0) **	ANALYTICAL P(>0) **	% DIFFERENCE	DATA
Emergency Telephone Circuits	.0077	.0037	.4	Table 5.3
Emergency Operators	.012	.0082	.39	Table 5.5
Dispatchers	.035	.021	1.42	Table 5.7
Radio Dispatch Channels	.0387	.028	1.07	Table 5.8
Radio Medical Channels	.041	.0495	.85	Table 5.9
Medical Units				
1) Uncorrected	.066	.0306	3.54	Table 5.11
2) Corrected*	.066	.0626	.34	

*(See subsection 5.2.4 for analysis)

** (Proportion)

complicate the server analysis because it has been observed in queueing studies that the operational rate of an individual server increases to some higher level as system load increases. This is why some tension is often maintained in server systems by the avoidance of excessive overstaffing. Another important consideration is controlling the mean service rate (μ) of emergency calls so as to minimize the variation in answering time. This variation is often controlled through operational procedures, operator training, and citizen education.

In the analysis of data from emergency operators and dispatchers, the Erlang C equation and attendant assumptions were utilized as in the previous subsection. The queueing discipline for Erlang C assumes that calls are served in the order of arrival. This is an oversimplification for most emergency systems because some priorities exist when resources are finite. The degree to which the queueing discipline departs from first-in first-out (FIFO) should be evaluated by the EMS system planners to determine if it compromises the use of Erlang C in their particular systems. This study assumes a FIFO queueing discipline.

The emergency operator traffic is set forth in Table 5-5. This is the same column and data format used in the previous subsection. Comparing the analytical and simulation computations as in subsection 5.2.1., the P(>0) is as shown in Table 5-4. The net difference between the analytical and simulation techniques is .39%. This difference seems to indicate that the simulation model closely approximates the analytical calculations. The reader is encouraged to review the assumptions and perform the data manipulations using

Table 5-5. Emergency Call Operator Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation
1	436	73	1
2	382	111	8
3	403	166	28
4	423	72	2
5	428	71	1
6	399	72	0
7	407	71	2
8	446	71	5
9	428	71	5
10	464	73	2
11	447	75	3
12	458	73	8
13	402	72	2
14	407	70	5
15	389	70	1
16	408	134	31
17	415	68	1
18	412	73	5
19	427	81	2
20	418	75	2
21	388	161	44
22	366	73	0
23	441	70	4
24	409	69	2
25	419	74	1
26	456	72	3
27	412	70	1
28	436	74	2
29	409	72	4
30	400	79	5
Total Events	12,535	-	152
Mean ($\bar{x}$)	418	82	
Variance (s^2)	525	648	
STD. DEV. (s)	23	26	
Mean Arrival Rate (λ) Per Hour	17.42	-	

Note: Three servers (call operators) were used in these simulation runs.

equation (5.2) to verify the data presented in Table 5-4. The same procedure was followed for dispatcher analysis, with the data set forth in Table 5-6 and the summary in Table 5-4.

An additional test was performed for the emergency operator to determine the sensitivity of the model to changes in server levels. The emergency operator server level was run with 2, 3, and 4 servers with all other model variables held constant. The same random seeds for each simulation run were used as set forth in Table 5-1. The data collected for the sensitivity analysis are included in Table 5-7 and are summarized below:

Number of Servers	P(>0)		
	Simulation	Analytical	% Difference
2	.0880	.0850	.30
3	.0143	.0065	.78
4	.0043	.0020	.23

The sensitivity of the model as indicated in the above summary provides a clear choice of alternatives. This should not imply that additional factors are not involved in server staffing decisions, rather the desired grade of service can be selected by examining the traffic load.

Thus far in the study only P(>0) has been considered. Operationally, this P(>0) would probably be revised to reflect some probability of delay greater than time, t, expressed as P(>t).

5.2.3. Radio Dispatch and Emergency Medical Channel Analysis

The use of radio dispatch channels to alert and direct medical and other resources to the emergency scene was employed at a number of

Table 5-6. Dispatcher Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation
1	389	107	2
2	339	187	23
3	354	281	60
4	357	137	8
5	375	121	4
6	335	109	3
7	369	122	4
8	393	111	6
9	394	109	11
10	379	112	4
11	399	154	22
12	401	111	9
13	344	113	6
14	340	109	8
15	337	112	6
16	360	230	62
17	360	112	1
18	341	109	6
19	376	144	13
20	391	114	6
21	335	244	55
22	309	109	2
23	388	108	11
24	357	109	3
25	352	124	8
26	382	108	4
27	353	111	3
28	390	117	8
29	347	114	8
30	360	135	18
Total Events	10,906	-	384
Mean ($\bar{x}$)	364	133	
Variance (s^2)	538	1900	
STD. DEV. (s)	23.6	44.3	
Mean Arrival Rate (λ) Per Hour	15.17	-	

Note: Three servers (dispatchers) were used in these simulation runs.

Table 5-7. Model Sensitivity to Emergency Operator Changes

Simulation Run	Arrival Rate For 24 Hour Simulation			Mean Service Rate (seconds) (μ)			Delay>0 For 24 Hour Simulation p(0)		
	S=2	S=3	S=4	S=2	S=3	S=4	S=2	S=3	S=4
11	415	447	418	71	75	71	17	3	0
12	400	458	378	72	72	204	17	8	5
13	416	402	419	74	72	75	28	2	0
14	403	407	388	71	70	151	26	5	2
15	443	389	438	73	70	73	29	1	0
16	364	408	448	171	134	129	53	31	4
17	380	415	425	164	68	71	39	1	0
18	422	412	376	73	73	72	26	5	0
19	445	427	389	131	81	221	101	2	5
20	428	418	428	74	75	74	27	2	2
Total Event	4116	4183	4107	-	-	-	363	60	18
Mean ($\overline{x}$)	412	418	411	97	79	114.1			
Variance (s^2)	598	388	602	1531	343	3141			
STD. DEV. (s)	25.8	20.8	25.9	41.2	19.5	59			
Mean Arrival Rate (λ) Per Hour	17.17	17.42	17.13	-	-	-			

different operational points within the simulation model. These included the actual medical unit dispatch, medical unit call-back for assistance, service unit notification and selected interagency coordination. The radio dispatch message lengths and time intervals between messages were assumed to have an exponential distribution because of the emergency event generation techniques programmed in Process P1.0. This assumption also appears to be valid based on empirical data collected in APCO Project III, Phase 2, conducted by the ITT Research Institute (1969).

The radio-dispatch data collected during the simulation runs are set forth in Table 5-8 and summarized in Table 5-4. Two dispatch channels were used in the simulation. As noted in Section 4, the model employed several subroutines to simulate radio channel congestion, interference and fading. The net difference between the analytical and simulation technique was 1.07%; this was considered an acceptable approximation. The P(>0) was .0387 for the simulation model and .028 for the analytical technique calculated for two dispatch channels. If this grade of service is judged to be unacceptable by local users, then one or more of three primary parameters would have to be changed (i.e., μ, λ, and/or the number of servers). Dispatch channel discipline policies can also play an important role in reducing mean service rate (μ) and mean arrival rate (λ).

There are a number of different operational strategies and theories for assigning and using medical control channels. In this model, the medical control channels are dynamically assigned by the dispatcher and not released until the medical unit completes serving the emergency event. The medical channel is assigned as the medical

Table 5-8. Radio Dispatch Channel Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation
1	333	48	4
2	305	115	24
3	306	197	50
4	318	75	15
5	327	60	5
6	305	47	3
7	324	62	6
8	338	50	1
9	355	48	9
10	289	53	7
11	354	90	30
12	356	49	6
13	291	49	7
14	308	46	2
15	303	52	6
16	330	146	54
17	316	50	4
18	291	46	11
19	329	80	15
20	365	51	10
21	301	159	36
22	281	48	8
23	345	46	4
24	311	48	3
25	308	62	11
26	329	47	3
27	307	49	2
28	340	55	11
29	308	51	4
30	325	70	20
Total Events	9598	-	371
Mean ($\bar{x}$)	320	68.3	
Variance (s^2)	458	1364	
STD. DEV. (s)	21.8	37.6	
Mean Arrival Rate (λ) Per Hour	13.33	-	

Note: Two servers (dispatch channels) were used in these simulation runs.

unit is enroute to the emergency scene so that coordination can be effected with the medical control facility. Whether this early medical channel assignment justifies the longer mean service rate (μ) must be determined by local EMS area policy and traffic analysis. There are differing opinions among physicians concerning the long range role of LMR in the delivery of EMS services. Some physicians have said that future communications requirements will be significantly lower than they are today, partly because legal requirements that influence current LMR use will eventually be modified. Other physicians have said that communications will play a larger role in paramedic operations in the future because of improved training and technology (Melnick, 1974).

Eight medical control channels were used in the simulation runs. The traffic data for these runs are set forth in Table 5-9. The mean medical channel service rate (μ) was approximately 16 minutes. Although the values used in this model do not represent any specific EMS system, this mean service rate is quite similar to data calculated by M. Melnick (1974) in a study for Los Angeles County. All EMS managers and planners are encouraged to review this Los Angeles County study for EMS telecommunications technical considerations.

A sensitivity analysis was conducted on the radio medical channels for 8, 9, and 10 servers (channels). The data for these simulation runs are set forth in Table 5-10 and summarized below:

Table 5-9. Radio Medical Channel Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation
1	359	995	29
2	319	980	16
3	328	988	8
4	342	977	9
5	357	961	3
6	319	996	1
7	350	971	6
8	376	913	16
9	378	976	26
10	364	940	12
11	375	950	21
12	388	997	32
13	330	956	5
14	331	863	5
15	319	1002	21
16	342	929	8
17	347	946	16
18	329	1003	11
19	360	961	10
20	366	959	16
21	319	999	17
22	290	1035	7
23	369	938	29
24	337	965	15
25	340	976	4
26	361	921	7
27	336	969	9
28	368	985	47
29	334	909	11
30	343	956	8
Total Events	10,376	-	425
Mean ($\bar{x}$)	346	964	
Variance (s^2)	485	1165	
STD. DEV. (s)	22.4	34.7	
Mean Arrival Rate (λ) Per Hour	14.42	-	

Note: Eight servers (channels) were used in these simulation runs.

Table 5-10. Model Sensitivity to Radio Medical Channel Changes

Simulation Run	Arrival Rate For 24 Hour Simulation			Mean Service Rate (seconds) (μ)			Delay>0 For 24 Hour Simulation P(0)		
	S=8	S=9	S=10	S=8	S=9	S=10	S=8	S=9	S=10
11	375	362	368	950	948	963	21	13	2
12	388	378	332	997	1013	1011	32	2	3
13	330	339	376	956	966	971	5	16	4
14	331	331	344	863	906	864	5	3	1
15	319	330	196	1002	973	1337	21	3	0
16	342	324	348	929	912	937	8	3	0
17	347	363	334	946	956	936	16	1	0
18	329	358	363	1003	970	1028	11	1	0
19	360	213	342	961	1087	982	10	5	1
20	366	357	340	959	973	968	16	5	1
Total Events	3487	3355	3343	-	-	-	145	52	12
Mean ($\overline{x}$)	349	336	334	957	970	1000			
Variance (s^2)	464	1943	2320	1555	2371	14459			
STD. DEV. (s)	22.7	46.5	50.8	41.6	51.3	126.8			
Mean Arrival Rate (λ) Per Hour	14.54	14.0	13.92	-	-	-			

Number of Servers	P(>0)		
	Simulation	Analytical	% Difference
8	.0416	.0499	.83
9	.0155	.0170	.15
10	.0036	.0070	.34

As noted with the call operator sensitivity analysis, the P(>0) would probably be revised to some P(>t) to allow for some locally acceptable delay expressed in terms of "t". The model sensitivity noted above provides clearly defined level-of-service alternatives for the decision maker. These alternatives, however, must be considered within the framework of the various simulation model assumptions and the assigned numerical delay values.

5.2.4. Medical Unit Traffic Analysis

The primary medical unit delay components were directly related to transit time. The role of ALS to help mitigate these transit delay components was discussed in previous chapters. Data were collected during the simulation runs to permit calculation of the ALS reduction in delay. This simulated reduction is shown in Figure 5-5 as compared to a BLS system. In capturing these data, it was assumed that BLS medical units had to reach a medical facility for ALS to commence. The ALS medical units were assumed to commence advanced procedures after patient triage at the medical emergency scene. The advanced procedures were authorized by protocols and LMR communications.

The medical unit traffic data are set forth in Table 5-11 and summarized in Table 5-4. In comparing the simulation and analytical

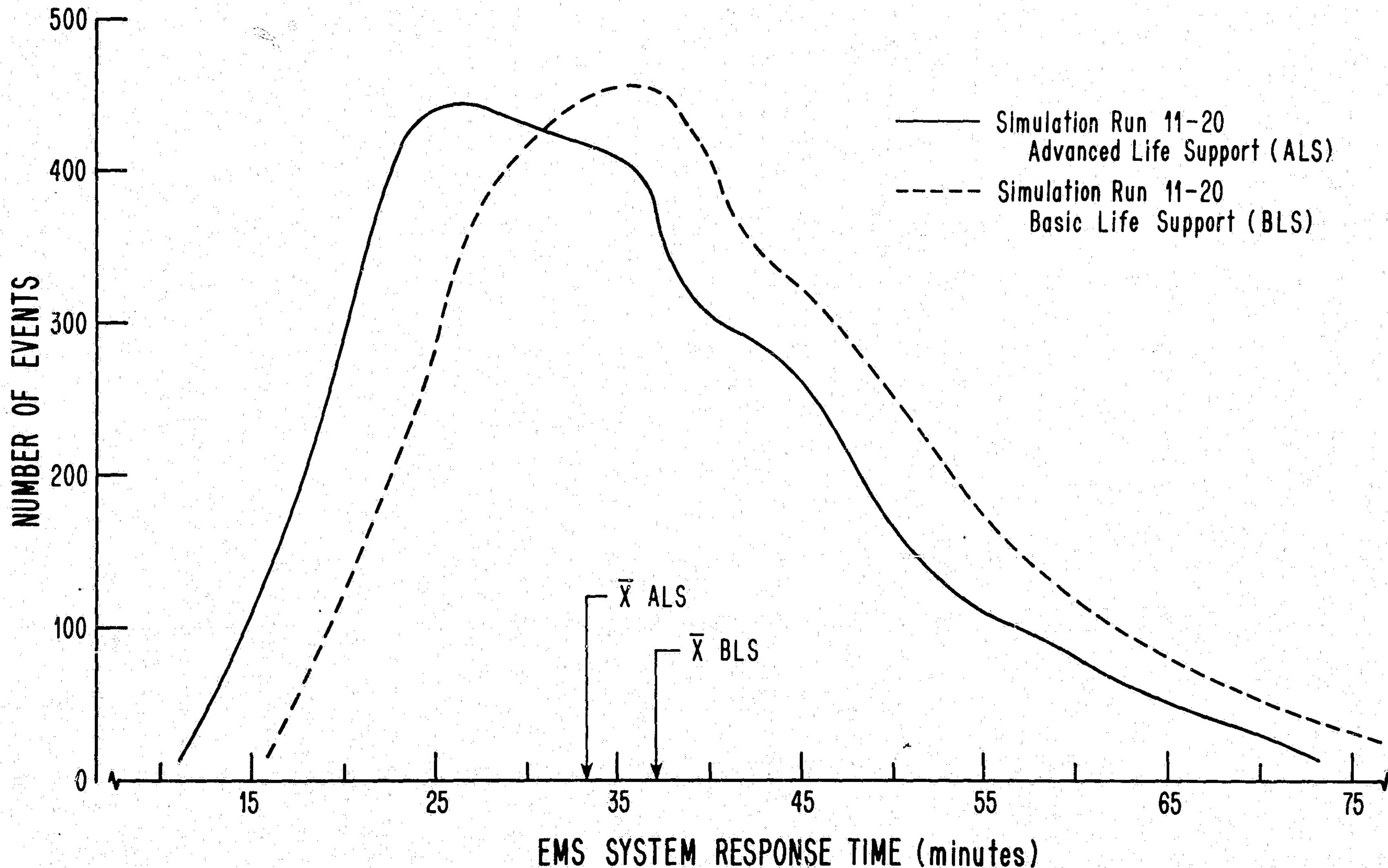


Figure 5-5. ALS and BLS response time comparisons.

Table 5-11. Medical Unit Traffic Data

Simulation Run	Arrival Rate For 24 Hour Simulation	Mean Service Rate (seconds) (μ)	Delay>0 For 24 Hour Simulation
1	359	1196	0
2	319	2025	49
3	328	2394	94
4	342	2262	47
5	357	2117	31
6	319	1334	0
7	350	1706	31
8	376	1634	6
9	378	1605	2
10	364	1819	16
11	376	2025	52
12	388	1707	14
13	330	1843	5
14	331	1199	0
15	319	1706	8
16	342	2234	75
17	347	1515	10
18	329	1461	0
19	360	2100	56
20	367	1854	14
21	319	2560	77
22	290	1885	1
23	369	1219	0
24	337	1407	1
25	340	1937	33
26	361	1208	0
27	336	1646	2
28	368	1467	16
29	334	1512	10
30	343	1846	34
Total Events	10,378	-	684
Mean ($\bar{x}$)	346	1747	
Variance (s^2)	488	128,852	
STD. DEV. (s)	23	365	
Mean Arrival Rate (λ) Per Hour	14.42	-	

Note: Thirteen servers (medical units) were used in these simulation runs.

computations of P(>0), a 3.54% net difference was noted. This difference was substantially out of line with the other traffic comparisons. A subprocess analysis revealed that three subroutines designed to simulate medical unit mechanical failure accounted for the high net difference value. As the model was programmed, if a medical unit was transferred to the mechanical failure subroutine it was lost for the remainder of the simulation run. This effectively reduced the number of medical unit servers from 13 to approximately 11.8. Using this corrected server factor, the analytical process was repeated and the results were compatible with previous values. These revised values are shown in Table 5-4. The use of both the analytical and simulation techniques provides a very useful self check in traffic analysis.

A number of research articles in the reviewed literature addressed the problems of medical unit location, deployment strategies, inter-jurisdictional medical response and cost/service tradeoff factors. While these areas are beyond the scope of this study, they are included in the Bibliography and Appendix A.

6. CONCLUSION

6.1. Summary

The purpose of this study was to conceptualize, to structure, and to demonstrate a basic EMS simulation model, a model which would assist communication managers and planners in designing, modifying and evaluating their EMS telecommunications system.

The EMS processes were factored into subprocesses to improve the user's conceptual understanding of the system and the flow charts were developed to provide a visual representation of the total structure. The emphasis on the conceptual and structural development was designed to allow the user to understand more clearly and to compare the time delays contributed by the various subprocesses of the model. It was anticipated that this technique would not only allow the user to understand better the various delay components, but also to visualize the organizational and economic elements from an EMS system perspective.

While the study focused on computer simulation, it was not implied that the users had to use simulation to evaluate their EMS system. Section 5 examined the simulation and analytical techniques for evaluating complex server systems and found them to be close approximations given the assumptions presented in the previous chapters.

The next subsection will briefly describe some of the primary problems involved in simulation modeling and modeling in general.

6.2. Observations

- Model Assumptions

  This study assumed that time was a critical variable in the delivery of emergency medical care. This implied that a reduction in time delay to some finite minimum would improve emergency care. The techniques used in this study were designed to explicate these delay subprocesses. The study also assumed that a Poisson distribution approximated the occurrence of emergency medical events in an EMS area. This assumption obviously facilitated a comparison between the simulation and analytical techniques for the purpose of model validation. The user, however, is encouraged to verify empirically the distributional properties of emergency events in their EMS area before accepting the Poisson as an approximation of emergency event occurrence.

- Autocorrelation

  The model user is cautioned to consider carefully the autocorrelation effects in simulation modeling. This effect is characterized by the queue of one server subsystem impacting on the queue of another. This is not unlike actual EMS system performance; however, simulation model results can be very misleading if these effects are misinterpreted. The validation and sensitivity analysis techniques discussed in Section 5 can assist the user in evaluating the impact and relative degree of autocorrelation. J. F. Jennings, Jr. (1978) suggests that Gaussian and diffusion approximations might be more appropriate in server systems which are more heavily loaded.

- Initial Bias

  As demonstrated in this study, initial bias was found to have a minimal effect if averaged over a 24-hour period. This approach may be somewhat oversimplified because in some EMS systems the initial bias and other spurious effects may be prematurely discounted. Users are cautioned to analyze system loading carefully as it affects their EMS telecommunications system.

- Required Research

  The EMS processes P1.0, P2.0, and P3.0 require far greater factoring to understand the various delay components. These three processes are generally considered outside the direct responsibility of most public institutions and as a result have received less research and operational consideration.

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APPENDIX A

CROSS REFERENCE MATRIX

This appendix is a cross reference between flow chart decision points/ subprocess delay blocks and relevant bibliographic references. Decision point values (D) are shown as proportions. Delay values (P) are in seconds.

SYMBOL KEY:

*	Mean interarrival time modified by a distribution function
**	Delay depends on the server queue
***	Unconditional transfer

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
D1	RENDER EMERGENCY ASSISTANCE?	.25		3,6,10,22,36,44,48,54
D1(P2.0)	EMERGENCY EVENT DETECTED?	.001		
D1(P3.0)	ACTIVE AID?	.75		3,10,44,45,54
D1(P4.0)	USE PUBLIC TELEPHONE SYSTEM?	.10		2,10,30,47a,61
D1(P4.1.0)	KNOW EMERGENCY NUMBER?	.50		1,2,10,14,28,61
D1(P4.2.0)	RADIO AVAILABLE?	.25		13,75,88
D1(P4.3.0)	CALL BOX LOCATED?	.50		
D1(P5.0)	USE DIRECT DISPATCH?	***		1,12,28,30,62,63
D1(P5.2.0)	MEDICAL RESPONSE REQUIRED?	.10		10,35,39
D1(P5.3.0)	CALL TRANSFER COMPLETE?	.05		76
D1(P6.0)	MEDICAL UNIT ENROUTE DELAY?	.20		3,8,14,58,92
D1(P7.0)	RADIO CALL RECEIVED BY DISPATCHER?	.10		4,16,29a,40,75,80,96
D1(P8.0)	DECISION TO TRANSPORT?	.20		10,39
D1(P9.0)	DECISION TO TRANSPORT?	.20		10,39
D2	ADDITIONAL SERVICE/EQUIPMENT REQUIRED?	.05		8,66
D2(P3.0)	REQUEST ADDITIONAL ASSISTANCE?	.20		10
D2(P4.0)	USE LAND/MOBILE RADIO SYSTEM?	.50		10,16,28,33,67,75,88
D2(P4.1.0)	DIAL OPERATOR?	.50		28,37,61,65
D2(P4.2.0)	RADIO LOCATED?	.80		67,68
D2(P4.3.0)	BOX OUT OF ORDER?	.10		

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
D2(P5.0)	USE CALL RELAY?	.15		1,12,28,30,62,63
D2(P5.2.0)	ADDITIONAL INFORMATION REQUIRED?	.10		39,76
D2(P6.0)	MEDICAL UNIT BREAKDOWN?	.001		
D2(P7.0)	DISPATCHER RECEIVED MESSAGE?	.10		4,16,29a,40,75,80,96
D2(P8.0)	MEDICAL UNIT ENROUTE DELAY?	.20		3,8,14
D2(P9.0)	MEDICAL CONTROL AVAILABLE?	.05		△
D3	ADVANCED LIFE SUPPORT AVAILABLE?	.50		3,50
D3(P4.0)	USE CALL BOX SYSTEM?	.50		10
D3(P4.1.0)	COIN REQUIRED FOR TELEPHONE?	.75		30
D3(P4.2.0)	RADIO RELAY REQUIRED?	.50		13,16,29a,33,75,88
D3(P5.0)	USE CALL TRANSFER?	.50		1,12,28,30,62,63
D3(P5.2.0)	ADDITIONAL INFORMATION REQUIRED?	.10		39,76
D3(P6.0)	TRAFFIC/CROWD CONTROL AT SCENE?	.20		
D3(P7.0)	SERVICE UNIT RECEIVED MESSAGE?	.10		16,29a,40,75,80,96
D3(P8.0)	MEDICAL UNIT BREAKDOWN?	.001		
D3(P9.0)	MEDICAL UNIT ENROUTE DELAY?	.20		3,8,14
D4(P4.1.0)	COINS LOCATED?	.25		
D4(P4.2.0)	RADIO CHANNEL AVAILABLE?	.50		4,13,16,29a,33,75,88
D4(P5.2.0)	RADIO DISPATCH TO MEDICAL UNIT?	.25		28,47a,75,78,80
D4(P7.0)	SERVICE UNIT ENROUTE DELAY?	.20		8

△ 3,5,15,23,29,47,47a,89,90,91

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
D4(P8.0)	MEDICAL FACILITY ADVISED OF ARRIVAL?	.10		3,5,15,28,47a,58,75,90,91
D4(P9.0)	MEDICAL UNIT BREAKDOWN?	.001		
D5(P4.1.0)	COIN REQUIRED FOR TELEPHONE?	.75		30
D5(P4.2.0)	RADIO MESSAGE RECEIVED?	.25		16,29a,40,75
D5(P5.2.0)	RADIO CALL RECEIVED BY MEDICAL UNIT?	.05		4,16,29a,40,75,80,96
D5(P9.0)	MEDICAL FACILITY ADVISED OF ARRIVAL?	.10		3,5,15,28,47a,58,75,90,91
D6(P4.1.0)	COINS LOCATED?	.25		
D6(P4.2.0)	USE PUBLIC TELEPHONE SYSTEM?	.90		
D6(P5.2.0)	DISPATCH MESSAGE RECEIVED?	.05		4,16,29a,40,47a,75,80,96
D7(P4.1.0)	EMERGENCY TELEPHONE CIRCUITS BUSY?	.001		1,2,30,80,96
D8(P4.1.0)	CORRECT TELEPHONE NUMBER?	.01		61,76
D8(P5.2.0)	TELEPHONE CALL ANSWERED?	.05		2
D9(P4.1.0)	EMERGENCY CALL ANSWERED?	.01		1,12,30,62,63,76,80,96
D9(P5.2.0)	RADIO CALL RECEIVED BY DISPATCHER?	.10		4,20,29a,40,75,80,96
D10(P5.2.0)	DISPATCHER RECEIVED MESSAGE?	.05		4,16,29a,40,75,80,96

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
P1.0	EMERGENCY MEDICAL EVENT OCCURRENCE	180*		6,45
P2.1	EMERGENCY MEDICAL EVENT DETECTION	360*		△
P3.1	ANALYZE/RENDER AID	360,180		3,10
P3.2	PRIVATE RESOURCES	360,60		
P3.3	DECIDE WHOM TO NOTIFY	60,30		10,28,61,62,65
P3.4	DECIDE HOW TO NOTIFY	30,15		10,28,61,62,65
P4.1.1	LOCATE PRIVATE/PUBLIC TELEPHONE	180,60		2,10
P4.1.2	DIAL OPERATOR	5,2		28,37,61,65
P4.1.3	OPERATOR DELAY	30,15		28,37,61,65
P4.1.4	LOCATE COINS	10,5		
P4.1.5	LOOK UP EMERGENCY NUMBER	20,10		61,65
P4.1.6	LOCATE COINS	10,5		
P4.1.7	DIAL EMERGENCY NUMBER	7,2		1,2,14,76
P4.1.8	CAPTURE EMERGENCY TELEPHONE CIRCUIT	**		▲
P4.1.9	EMERGENCY TELEPHONE RINGDOWN	6,2		1,2,62,63
P4.1.10	CHECK EMERGENCY TELEPHONE NUMBER	20,10		61
P4.1.11	BUSY/NO ANSWER DELAY	12,4		1,2,30,76,80,96
P4.2.1	LOCATE RADIO	360,60		67,68
P4.2.2	RADIO DELAY COORDINATION	60,15		16,29a,88
P4.2.3	WAIT FOR CHANNEL	60,40		16,29a,75

△ 3,6,10,22,36,38,44,45,48,54,67,68

▲ 1,2,7,12,14,2[illegible],[illegible],61,62,63,76,80,96

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
P4.2.4	SEND RADIO MESSAGE	30,10		4,75
P4.2.5	REPEAT MESSAGE COORDINATION	30,15		16,29a,75
P4.2.6	CONSOLIDATE INFORMATION	10,5		39
P4.2.7	CONTACT PUBLIC SAFETY AGENCY	15,5		13,33,88
P4.3.1	LOCATE CALL BOX	360,180		
P4.3.2	ACTIVATE CALL BOX	10,5		
P4.4.1	DETERMINE AGENCY LOCATION	120,30		
P4.4.2	TRAVEL TIME TO AGENCY	600,300		
P4.4.3	CAPTURE DESK PERSON	**		7,21
P4.4.4	RELATE EMERGENCY DETAILS	60,20		
P4.4.5	CONSOLIDATE INFORMATION	10,5		
P4.4.6	CONTACT AGENCY DISPATCHER	5,2		
P5.2.1	CAPTURE AN OPERATOR	**		△
P5.2.2	OBTAIN EMERGENCY INFORMATION	40,20		10,35,39,61,64,76,96
P5.2.3	TERMINATE EMERGENCY CALL	5,2		1,30,35,39,76
P5.2.4	CONSOLIDATE INFORMATION	10,3		39
P5.2.5	CAPTURE A DISPATCHER	**		2,7,14,21,64,76,96
P5.2.6	RELAY INFORMATION TO DISPATCHER	15,5		30,39,76
P5.2.7	REVIEW CALL OPERATOR INFORMATION	10,5		39
P5.2.8	DETERMINE EMERGENCY LOCATION	15,5		35,39,64,76,78,80

△ 1,7,12,14,21,61,63,64,76,80,96

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE MODEL	NUMERICAL VALUE USER	BIBLIOGRAPHY REFERENCE(S)
P5.2.9	TYPE/AVAILABILITY OF MEDICAL UNITS	20,10		△
P5.2.10	CAPTURE RADIO CHANNEL	**		2,4,7,21,40,75,80,87,91,96
P5.2.11	TRANSMIT MEDICAL UNIT CALL SIGN	10,3		16,25,52,80
P5.2.12	MEDICAL UNIT RADIO REPLY	10,3		16,25,80
P5.2.13	RING BACK EMERGENCY CALLER	30,10		30,39,76
P5.2.14	SEND DISPATCH MESSAGE	15,5		25,47a,80
P5.2.15	MEDICAL UNIT ACKNOWLEDGE MESSAGE	10,3		16,25,58,80
P5.2.16	RING BACK EMERGENCY CALLER	30,10		30,39,76
P5.2.17	OPERATOR COORD. NON MEDICAL RESPONSE	70,20		80
P5.2.18	(NOT USED)			
P5.2.19	TELEPHONE THE MEDICAL UNIT STATION	10,3		2,62
P5.2.20	RELATE DISPATCH MESSAGE	15,5		39
P5.2.21	ACKNOWLEDGE MESSAGE RECEIVED	10,3		58
P5.2.22	MEDICAL UNIT CLEAR THE STATION	20,5		
P5.2.23	(NOT USED)			
P5.2.24	CAPTURE A RADIO CHANNEL	**		2,4,20,21,80,87,96
P5.2.25	ALERT DISPATCHER	10,3		20,25,28,52,80
P5.2.26	CAPTURE A DISPATCHER	**		2,4,14,21,65,76,80,96
P5.2.27	DISPATCHER RADIO REPLY	10,3		25,80
P5.2.28	RELATE PROBLEM TO DISPATCHER	20,10		25,39

△ 3,8,14,35,38,39,41,48,56,58,66,78,80,92

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
P5.2.29	DISPATCHER EVALUATES MED. UNIT PRIORITIES	30,15		△
P5.2.30	REPEAT MESSAGE COORDINATION	30,10		16,29a,75,80
P5.2.31	CAPTURE MEDICAL CONTROL CHANNEL	**		▲
P5.2.32	REPEAT MESSAGE COORDINATION	30,10		16,29a,75
P5.3.1	CAPTURE AN OPERATOR	**		1,2,7,12,14,21,64,76,96
P5.3.2	OBTAIN BASIC TRANSFER INFORMATION	15,5		10,39,64,76,96
P5.3.3	TRANSFER CALLER TO APPROPRIATE AGENCY	5,2		76
P5.4.1	CAPTURE AN OPERATOR	**		1,2,7,14,21,64,76,96
P5.4.2	OBTAIN BASIC REFERRAL INFORMATION	30,15		10,39,64,96
P5.4.3	PROVIDE INFORMATION TO CALLER	30,15		39,64
P6.1	MEDICAL UNIT ENROUTE	15,5		
P6.2	ABNORMAL TRAVEL DELAY	120*		
P6.3	MEDICAL UNIT TRAVEL TIME	360*		3,8,45,58,92
P6.4	TRAFFIC/CROWD DELAY	60,30		
P6.5	MED. UNIT INITIAL SCENE EVALUATION	60,30		3
P7.1	CAPTURE A RADIO CHANNEL	**		2,4,7,21,29a,80,87,96
P7.2	ALERT DISPATCHER	10,3		16,25,28,52,80
P7.3	CALL DISPATCHER AGAIN	10,3		16,29a,75,80,96
P7.4	CAPTURE A DISPATCHER	**		2,4,7,21,80
P7.5	DISPATCHER RADIO REPLY	10,3		16,25,80

△ 3,8,14,35,38,39,41,56,58,66,78,80

▲ 2,5,7,15,16,21,28,29,29a,40,47a,80,87,88,89,91,96

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE		BIBLIOGRAPHY REFERENCE(S)
		MODEL	USER	
P7.6	RELATE PROBLEM TO DISPATCHER	20,10		4,25,35,39
P7.7	REPEAT MESSAGE COORDINATION	20,10		16,29a,75,80,96
P7.8	CAPTURE A SERVICE UNIT	**		2,4,7,11,21
P7.9	SERVICE UNIT RADIO REPLY	10,3		16,25
P7.10	RELATE PROBLEM TO SERVICE UNIT	20,10		25,39
P7.11	REPEAT MESSAGE COORDINATION	20,10		16,75,80,96
P7.12	SERVICE UNIT TRAVEL TIME	360*		8
P7.13	ABNORMAL TRAVEL DELAY	120*		
P7.14	PROVIDE SERVICE AT SCENE	600,180		11
P8.1	PATIENT TRIAGE	60,30		3,45,58
P8.2	UNITS CLEAR THE SCENE	30,10		
P8.3	TRANSFER PATIENT TO MEDICAL UNIT	15,5		
P8.4	MEDICAL UNIT CLEAR THE EMERGENCY SCENE	15,5		3,58
P8.5	ABNORMAL TRAVEL TIME	120*		
P8.6	MEDICAL UNIT TRAVEL TIME	360*		3,8,45,58
P8.7	MEDICAL FACILITY PREPERATION DELAY	30,10		5,28
P8.8	OFFLOAD PATIENT FROM MEDICAL UNIT	15,5		
P8.9	MEDICAL FACILITY TRANSPORT DELAY	15,5		
P9.1	PATIENT TRIAGE	60,30		3,45,58
P9.2	UNITS CLEAR THE EMERGENCY SCENE	30,10		

REFERENCE NUMBER	DESCRIPTION	NUMERICAL VALUE MODEL	NUMERICAL VALUE USER	BIBLIOGRAPHY REFERENCE(S)
P9.3	START ALS STABLIZATION	10,5		50
P9.4	ADVISE MED. CONTROL OF PATIENT CONDITION	15,5		3,15,28,29,47
P9.5	MEDICAL CONTROL DIRECTION	15,5		△
P9.6	TRANSFER PATIENT TO MEDICAL UNIT	15,5		
P9.7	MEDICAL UNIT CLEAR THE SCENE	15,5		3,58
P9.8	ABNORMAL TRAVEL DELAY	120*		
P9.9	MEDICAL UNIT TRAVEL TIME	360*		3,8,45,58
P9.10	MEDICAL FACILITY PREPERATION DELAY	30,10		5,28
P9.11	OFFLOAD PATIENT FROM MEDICAL UNIT	15,5		
P9.12	MEDICAL FACILITY TRANSPORT DELAY	15,5		

△ 3,15,28,29,47,47a,89,90,91

APPENDIX B

COMPUTER PROGRAM LISTING

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                                  CARD
                                                                                              NUMBER
        *
        *      MODEL RUN (CONFIG 1)
        *
               SIMULATE
        *
        *      FUNCTION DEFINITION(S)
        *
1        DIST1 FUNCTION    RN1,C24             EXPON DIST FUNCTION
1       0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
1       .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
1       .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
        *
2        DIST2 FUNCTION    RN2,C24             EXPON DIST FUNCTION
2       0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
2       .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
2       .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
        *
3        DIST3 FUNCTION    RN3,C24             EXPON DIST FUNCTION
3       0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
3       .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
3       .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
        *
4        DIST4 FUNCTION    RN4,C24             EXPON DIST FUNCTION
4       0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
4       .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
4       .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
        *
        *
        *      STORAGE CAPACITY DEFINITION(S)
1        AMBU  STORAGE     13                  MEDICAL UNITS
2        DESK  STORAGE     1                   AGENCY DESK PERSON
3        DISP  STORAGE     3                   DISPATCHERS
4        EMOPR STORAGE     3                   EMERGENCY CALL OPERATORS
5        RADIS STORAGE     2                   RADIO DISPATCH/COORD CHANNELS
6        RAMED STORAGE     8                   RADIO MEDICAL CONTROL CHANNELS
7        SERVU STORAGE     4                   EMERGENCY SERVICE UNITS
8        TELE  STORAGE     3                   EMERGENCY TELEPHONE CIRCUTS
        *
        *
        *      TABLE DEFINITION(S)
        *
1        RTIME TABLE       M1,900,300,16       TABLE FOR SYSTEM RESPONSE
2        ALSUP TABLE       M1,600,300,16       TABLE FOR ALS STARTUP
3        AMBU  QTABLE      AMBU,0,10,60        RESIDENCE TIME IN THE LINE
4        DISP  QTABLE      DISP,0,10,60        RESIDENCE TIME IN THE LINE
5        EMOPR QTABLE      EMOPR,0,10,60       RESIDENCE TIME IN THE LINE
6        RADIS QTABLE      RADIS,0,10,60       RESIDENCE TIME IN THE LINE
7        RAMED QTABLE      RAMED,0,10,60       RESIDENCE TIME IN THE LINE
8        SERVU QTABLE      SERVU,0,10,20       RESIDENCE TIME IN THE LINE
9        TELE  QTABLE      TELE,0,10,60        RESIDENCE TIME IN THE LINE
        *
        *
        *      *P1.0 EMERGENCY MEDICAL EVENT OCCURS
        *
      1        GENERATE    180,FN$DIST1        EMERGENCY EVENT OCCURS   P1.0
```

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS

   2           ADVANCE                               *GPSS OPR
        *
        *      *P2.0 EMERGENCY MEDICAL EVENT DETECTION
        *
   3    PBO    ADVANCE    360,FN$DIST2         EMERGENCY EVENT DETECT   P2.1
   4           TRANSFER   .001,,GPSS4          EMERG EVENT DETECTED     D1(P2.0)
        *
        *      *D1 RENDER EMERGENCY ASSISTANCE
        *
   5           TRANSFER   .25,,PBO             RENDER ASSISTANCE        D1
        *
        *      *P3.0 EMERGENCY MEDICAL ASSISTANCE PROCESS
        *
   6           TRANSFER   .75,,PCC             ACTIVE AID               D1(P3.0)
   7           ADVANCE    360,180              ANALYZE/RENDER AID       P3.1
   8           TRANSFER   .20,,PCB             REQUEST ADD ASSISTANCE   D2(P3.0)
   9    PCC    ADVANCE    60,30                DECIDE WHOM TO NOTIFY    P3.3
  10    PCD    ADVANCE    30,15                DECIDE HOW TO NOTIFY     P3.4
  11           TRANSFER   ,DAPDO                 *GPSS OPR
  12    PCB    ADVANCE    360,60               PRIVATE RESOURCES        P3.2
  13           TERMINATE                       STOP
  14    GPSS4  TERMINATE                       STOP
        *
        *      *P4.0 CITIZEN EMERGENCY ACCESS PROCESS
        *
        *           *P4.1 PUBLIC TELEPHONE SYSTEM
        *
  15    DAPDO  TRANSFER   .10,,DBPDO           USE PUBLIC TELE SYSTEM   D1(P4.0)
  16           ADVANCE    180,60               LOCATE PRIV/PUB TELE     P4.1.1
  17    DAPDA  TRANSFER   .50,,DBPDA           KNOW EMERGENCY NUMBER    D1(P4.1.0)
  18    DEPDA  TRANSFER   .75,,PDAF            COIN REQ FOR TELEPHONE   D5(P4.1.0)
  19    PDAG   ADVANCE    7,2                  DIAL EMERGENCY NUMBER    P4.1.7
  20           TRANSFER   .001,,PDAAA          EMERG TELE CIRCUTS BUSY  D7(P4.1.0)
  21    PDAH   ADVANCE                           *GPSS OPR
  22           QUEUE      TELE                   *GPSS STATISTICS
  23           ENTER      TELE                 CAPTURE EMERG TELE CIR   P4.1.8
  24           DEPART     TELE                   *GPSS STATISTICS
  25           ADVANCE    6,2                  EMERG TELE RINGDOWN      P4.1.9
  26           TRANSFER   .01,,PDAAO           CORRECT TELE NUMBER      D8(P4.1.0)
  27           TRANSFER   .01,,GPSS5           EMERG TELE ANSWERED      D9(P4.1.0)
  28           TRANSFER   ,DAPEO                 *GPSS OPR
  29    DBPDA  TRANSFER   .50,,DCPDA           DIAL OPERATOR            D2(P4.1.0)
  30           ADVANCE    20,10                LOOK UP EMERG NUMBER     P4.1.5
  31           TRANSFER   ,DEPDA                 *GPSS OPR
  32    DCPDA  TRANSFER   .75,,PDAD            COIN REQ FOR TELEPHONE   D3(P4.1.0)
  33    PDAB   ADVANCE    5,2                  DIAL OPERATOR            P4.1.2
  34           ADVANCE    30,15                OPERATOR DELAY           P4.1.3
  35           TRANSFER   ,PDAH                  *GPSS OPR
  36    PDAD   ADVANCE    10,5                 LOCATE COIN(S)           P4.1.4
  37           TRANSFER   .25,PDAB,PCD         COIN(S) LOCATED          D4(P4.1.0)
  38    PDAF   ADVANCE    10,5                 LOCATE COIN(S)           P4.1.6
  39           TRANSFER   .25,PDAG,PCD         COIN(S) LOCATED          D6(P4.1.0)
  40    PDAAO  LEAVE      TELE                   *GPSS OPR
  41           ADVANCE    20,10                CHECK TELE NUMBER        P4.1.10
  42           TRANSFER   ,DAPDA                 *GPSS OPR
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BLOCK                                                                              CARD
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                       NUMBER

  43    PDAAA  ADVANCE    12,4                  BUSY/NO ANSWER DELAY     P4.1.11      111
  44           TRANSFER   ,DEPDA                  *GPSS OPR                           112
  45    GPSS5  LEAVE      TELE                    *GPSS OPR                           113
  46           TRANSFER   ,PDAAA                  *GPSS OPR                           114
        *                                                                             115
        *           *P4.2 LAND/MOBILE RADIO SYSTEM                                    116
        *                                                                             117
  47    DBPDO  TRANSFER   .50,,DCPDO            USE LAND/MOBILE RAD SYS  D2(P4.0)     118
  48           TRANSFER   .25,,PDBA             RADIO AVAILABLE          D1(P4.2.0)   119
  49    DCPDB  TRANSFER   .50,,PDBB             RADIO RELAY REQUIRED     D3(P4.2.0)   120
  50    DDPDB  TRANSFER   .50,,PDBC             RADIO CHANNEL AVAILABLE  D4(P4.2.0)   121
  51    PDBD   ADVANCE    30,10                 SEND RADIO MESSAGE       P4.2.4       122
  52           TRANSFER   .25,,PDBE             RADIO MESSAGE RECEIVED   D5(P4.2.0)   123
  53           ADVANCE    10,5                  CONSOLIDATE INFORMATION  P4.2.6       124
  54           ADVANCE    15,5                  CONTACT APPROP AGENCY    P4.2.7       125
  55           TRANSFER   .90,,DAPDA            USE PUBLIC TELE SYSTEM   D6(P4.2.0)   126
  56           TRANSFER   ,PEBBD                  *GPSS OPR                           127
  57    PDBA   ADVANCE    360,60                LOCATE RADIO             P4.2.1       128
  58           TRANSFER   .80,DCPDB,PCD         RADIO LOCATED            D2(P4.2.0)   129
  59    PDBB   ADVANCE    60,15                 RADIO/RELAY COORD        P4.2.2       130
  60           TRANSFER   ,DDPDB                  *GPSS OPR                           131
  61    PDBC   ADVANCE    60,40                 WAIT FOR CHANNEL         P4.2.3       132
  62           TRANSFER   ,DDPDB                  *GPSS OPR                           133
  63    PDBE   ADVANCE    30,15                 REPEAT/MESSAGE COORD     P4.2.5       134
  64           TRANSFER   ,DDPDB                  *GPSS OPR                           135
        *                                                                             136
        *           *P4.3 CALL BOX SYSTEM                                             137
        *                                                                             138
  65    DCPDO  TRANSFER   .50,,PDDA             USE CALL BOX SYSTEM      D3(P4.0)     139
  66           ADVANCE    360,180               LOCATE CALL BOX          P4.3.1       140
  67           TRANSFER   .50,,PCD              CALL BOX LOCATED         D1(P4.3.0)   141
  68           TRANSFER   .10,,PCD              BOX OUT OF ORDER         D2(P4.3.0)   142
  69           ADVANCE    10,5                  ACTIVATE CALL BOX        P4.3.2       143
  70           TRANSFER   ,PDDC                   *GPSS OPR                           144
        *                                                                             145
        *           *P4.4 DIRECT CITIZEN CONTACT                                      146
        *                                                                             147
  71    PDDA   ADVANCE    120,30                DETERMINE AGENCY LOCAT   P4.4.1       148
  72           ADVANCE    600,300               TRAVEL TIME TO AGENCY    P4.4.2       149
  73    PDDC   ADVANCE                            *GPSS OPR                           150
  74           QUEUE      DESK                    *GPSS STATISTICS                    151
  75           ENTER      DESK                  CAPTURE DESK PERSON      P4.4.3       152
  76           DEPART     DESK                    *GPSS STATISTICS                    153
  77           ADVANCE    60,20                 RELATE EMERG DETAILS     P4.4.4       154
  78           ADVANCE    10,5                  CONSOLIDATE INFO         P4.4.5       155
  79           ADVANCE    5,2                   CONTACT AGENCY DISP      P4.4.6       156
  80           LEAVE      DESK                    *GPSS OPR                           157
  81           TRANSFER   ,PEBBD                  *GPSS OPR                           158
        *                                                                             159
        *      *P5.0 EMERGENCY ANSWERING AND DISPATCH PROCESS                         160
        *                                                                             161
        *           *P5.1 DIRECT DISPATCH PROCESS                                     162
        *                                                                             163
  82    DAPEO  TRANSFER   ,DBPEO                USE DIRECT DISPATCH      D1(P5.0)     164
        *                                                                             165
```

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BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS

        *            *P5.2 CALL RELAY PROCESS
        *
  83    DBPEO  TRANSFER   .15,,DCPEO         USE CALL RELAY          D2(P5.0)
  84           ADVANCE                        *GPSS OPR
  85           QUEUE      EMOPR               *GPSS STATISTICS
  86           ENTER      EMOPR              CAPTURE AN OPERATOR     P5.2.1
  87           DEPART     EMOPR               *GPSS STATISTICS
  88           ADVANCE    40,20              OBTAIN EMERGENCY INFO   P5.2.2
  89           TRANSFER   .10,,PEBAG         MEDICAL RESPONSE REQ    D1(P5.2.0)
  90           ADVANCE    5,2                TERMINATE EMERG CALL    P5.2.3
  91           LEAVE      TELE                *GPSS OPR
  92           ADVANCE    10,3               CONSOLIDATE INFO        P5.2.4
  93    DBPEB  TRANSFER   .10,,PEBAC         ADDITIONAL INFO REQ     D2(P5.2.0)
  94           QUEUE      DISP                *GPSS STATISTICS
  95           ENTER      DISP               CAPTURE A DISPATCHER    P5.2.5
  96           DEPART     DISP                *GPSS STATISTICS
  97           ADVANCE    15,5               RELAY INFO TO DISPATCH  P5.2.6
  98           LEAVE      EMOPR               *GPSS OPR
  99           ADVANCE    10,5               REVIEW CALL OPR INFO    P5.2.7
 100           ADVANCE    15,5               DETERMINE EMERG LOCAT   P5.2.8
 101    DCPEB  TRANSFER   .10,,PEBAF         ADDITIONAL INFO REQ     D3(P5.2.0)
 102    PEBI   ADVANCE    20,10              TYPE/AVAIL OF MED UNIT  P5.2.9
 103           TRANSFER   .25,,PEBAI         RADIO DISPATCH          D4(P5.2.0)
 104           QUEUE      RADIS               *GPSS STATISTICS
 105           ENTER      RADIS              CAPTURE RADIO CHANNEL   P5.2.10
 106           DEPART     RADIS               *GPSS STATISTICS
 107           ADVANCE    10,3               TRANSMIT MED UNIT CALL  P5.2.11
 108           TRANSFER   .05,,GPSS6         RADIO CALL REC MED UNIT D5(P5.2.0)
 109           ADVANCE    10,3               MED UNIT RADIO REPLY    P5.2.12
 110           QUEUE      AMBU                *GPSS STATISTICS
 111           ENTER      AMBU                *GPSS OPR
 112           DEPART     AMBU                *GPSS STATISTICS
 113    PEBAD  ADVANCE    15,5               SEND DISPATCH MESSAGE   P5.2.14
 114           TRANSFER   .05,,PEBCO         DISPATCH MESSAGE REC    D6(P5.2.0)
 115           ADVANCE    10,3               MED UNIT ACKNOW MESSAGE P5.2.15
 116           LEAVE      DISP                *GPSS OPR
 117           LEAVE      RADIS               *GPSS OPR
 118    PEBCA  ADVANCE                        *GPSS OPR
 119           QUEUE      RAMED               *GPSS STATISTICS
 120           ENTER      RAMED              CAPTURE MED CONT CHAN   P5.2.31
 121           DEPART     RAMED               *GPSS STATISTICS
 122           TRANSFER   ,PFA                *GPSS OPR
 123    PEBAG  LEAVE      TELE                *GPSS OPR
 124           ADVANCE    70,20              COORD NON MED RESPONSE  P5.2.17
 125           LEAVE      EMOPR               *GPSS OPR
 126           TERMINATE                     STOP
 127    PEBAC  ADVANCE    30,10              RING BACK EMERG CALLER  P5.2.13
 128           TRANSFER   ,DBPEB              *GPSS OPR
 129    PEBAI  ADVANCE    10,3               TELE MED UNIT STATION   P5.2.19
 130           TRANSFER   .05,,PEBI          TELE CALL ANSWERED      D8(P5.2.0)
 131           ADVANCE    15,5               RELATE DISPATCH MESSAGE P5.2.20
 132           ADVANCE    10,3               ACKNOWLEDGE MESSAGE     P5.2.21
 133           LEAVE      DISP                *GPSS OPR
 134           QUEUE      AMBU                *GPSS STATISTICS
 135           ENTER      AMBU                *GPSS OPR
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BLOCK                                                                                  CARD
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                           NUMBER

  136          DEPART     AMBU                  *GPSS STATISTICS                        221
  137          ADVANCE    20,5                MED UNIT CLEAR STATION   P5.2.22          222
  138          TRANSFER   ,PEBCA                *GPSS OPR                               223
  139   PEBAF  ADVANCE    30,10               RING BACK EMERG CALLER   P5.2.16          224
  140          TRANSFER   ,DCPEB                *GPSS OPR                               225
  141   GPSS6  LEAVE      RADIS                 *GPSS OPR                               226
  142          TRANSFER   ,PEBI                 *GPSS OPR                               227
  143   PEBBD  ADVANCE                          *GPSS OPR                               228
  144          QUEUE      RADIS                 *GPSS STSTISTICS                        229
  145          ENTER      RADIS               CAPTURE RADIO CHANNEL    P5.2.24          230
  146          DEPART     RADIS                 *GPSS STATISTICS                        231
  147   PEBBE  ADVANCE    10,3                ALERT DISPATCHER         P5.2.25          232
  148          TRANSFER   .10,,PEBBE          RADIO CALL REC BY DISP   D9(P5.2.0)       233
  149          QUEUE      DISP                  *GPSS STATISTICS                        234
  150          ENTER      DISP                CAPTURE A DISPATCHER     P5.2.26          235
  151          DEPART     DISP                  *GPSS STATISTICS                        236
  152          ADVANCE    10,3                DISPATCHER RADIO REPLY   P5.2.27          237
  153   PEBBH  ADVANCE    20,10               RELATE PROBLEM TO DISP   P5.2.28          238
  154          TRANSFER   .05,,PEBCB          DISPATCH REC MESSAGE     D10(P5.2.0)      239
  155          LEAVE      RADIS                 *GPSS OPR                               240
  156          ADVANCE    30,15               DISP EVAL MED UNIT PRI   P5.2.29          241
  157          TRANSFER   ,PEBI                 *GPSS OPR                               242
  158   PEBCB  ADVANCE    30,10               REPEAT MESSAGE COORD     P5.2.32          243
  159          TRANSFER   ,PEBBH                *GPSS OPR                               244
  160   PEBCO  ADVANCE    30,10               REPEAT MESSAGE COORD     P5.2.30          245
  161          TRANSFER   ,PEBAD                *GPSS OPR                               246
        *                                                                               247
        *          *P5.3 CALL TRANSFER PROCESS                                          248
        *                                                                               249
  162   DCPEO  TRANSFER   .50,,PEDA           USE CALL TRANSFER       D3(P5.0)          250
  163          QUEUE      EMOPR                 *GPSS STATISTICS                        251
  164          ENTER      EMOPR               CAPTURE AN OPERATOR      P5.3.1           252
  165          DEPART     EMOPR                 *GPSS STATISTICS                        253
  166          ADVANCE    15,5                OBTAIN BASIC TRANS INFO  P5.3.2           254
  167   PECC   ADVANCE    5,2                 TRANS CALLER APPROP AGY  P5.3.3           255
  168          TRANSFER   .05,,PECC           CALL TRANS COMPLETE      D1(P5.3.0)       256
  169          LEAVE      EMOPR                 *GPSS OPR                               257
  170          ADVANCE    60,40                 *GPSS OPR                               258
  171          LEAVE      TELE                  *GPSS OPR                               259
  172          TERMINATE                      STOP                                      260
        *                                                                               261
        *          *P5.4 CALL REFERRAL PROCESS                                          262
        *                                                                               263
  173   PEDA   ADVANCE                          *GPSS OPR                               264
  174          QUEUE      EMOPR                 *GPSS STATISTICS                        265
  175          ENTER      EMOPR               CAPTURE AN OPERATOR      P5.4.1           266
  176          DEPART     EMOPR                 *GPSS STATISTICS                        267
  177          ADVANCE    30,15               OBTAIN BASIC REF INFO    P5.4.2           268
  178          ADVANCE    30,15               PROVIDE INFO TO CALLER   P5.4.3           269
  179          LEAVE      TELE                  *GPSS OPR                               270
  180          LEAVE      EMOPR                 *GPSS OPR                               271
  181          TERMINATE                      STOP                                      272
        *                                                                               273
        *      *P6.0 EMERGENCY MEDICAL UNIT TRANSIT PROCESS                             274
  182   PFA    ADVANCE    15,5                MEDICAL UNIT ENROUTE     P6.1             275
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BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS

 183    DAPFO  TRANSFER   .20,,PFB          MED UNIT ENROUTE DELAY   D1(P6.0)
 184           TRANSFER   .001,,GPSS1       MED UNIT BREAKDOWN       D2(P6.0)
 185           ADVANCE    360,FN$DIST3      MED UNIT TRAVEL TIME     P6.3
 186    DCPFO  TRANSFER   .20,,PFD          TRAFFIC/CROWD CONTROL    D3(P6.0)
 187           ADVANCE    60,30             MED UNIT INITIAL EVAL    P6.5
 188           TRANSFER   ,DBO                *GPSS OPR
 189    PFB    ADVANCE    120,FN$DIST4      ABNORMAL TRAVEL DELAY    P6.2
 190           TRANSFER   ,DAPFO              *GPSS OPR
 191    GPSS1  LEAVE      RAMED               *GPSS OPR
 192           TRANSFER   ,PEBBD              *GPSS OPR
 193    PFD    ADVANCE    60,30             TRAFFIC/CROWD DELAY      P6.4
 194           TRANSFER   ,DCPFO              *GPSS OPR
        *
        *      *D2 ADDITIONAL SERVICE/EQUIPMENT REQUIRED
 195    DBO    TRANSFER   .05,DCO,PGA       ADDITIONAL SERV/EQUIP    D2
        *
        *      *P7.0 SERVICE UNIT DISPATCH AND TRANSIT PROCESS
        *
 196    PGA    ADVANCE                        *GPSS OPR
 197           QUEUE      RADIS               *GPSS STATISTICS
 198           ENTER      RADIS             CAPTURE RADIO CHANNEL    P7.1
 199           DEPART     RADIS               *GPSS STATISTICS
 200    PGB    ADVANCE    10,3              ALERT DISPATCHER         P7.2
 201           TRANSFER   .10,,PGC          RADIO CALL REC BY DISP   D1(P7.0)
 202           QUEUE      DISP                *GPSS STATISTICS
 203           ENTER      DISP              CAPTURE A DISPATCHER     P7.4
 204           DEPART     DISP                *GPSS STATISTICS
 205           ADVANCE.   10,3              DISPATCHER RADIO REPLY   P7.5
 206    PGF    ADVANCE    20,10             RELATE PROBLEM TO DISP   P7.6
 207           TRANSFER   .10,,PGG          DISP REC MESSAGE         D2(P7.0)
 208           QUEUE      SERVU               *GPSS STATISTICS
 209           ENTER      SERVU             CAPTURE A SERVICE UNIT   P7.8
 210           DEPART     SERVU               *GPSS STATISTICS
 211           ADVANCE    10,3              SERVICE UNIT RADIO REPLY P7.9
 212    PGAO   ADVANCE    20,10             RELATE PROB TO SER UNIT  P7.10
 213           TRANSFER   .10,,PGAA         SERV UNIT REC MESSAGE    D3(P7.0)
 214           LEAVE      DISP                *GPSS OPR
 215           LEAVE      RADIS               *GPSS OPR
 216           ADVANCE    360,FN$DIST2      SERV UNIT TRAVEL TIME    P7.12
 217    DDPGO  TRANSFER   .20,,PGAC         SERV UNIT ENROUTE DELAY  D4(P7.0)
 218           ADVANCE    600,180           PROVIDE SERV AT SCENE    P7.14
 219           LEAVE      SERVU               *GPSS OPR
 220           TRANSFER   ,DCO                *GPSS OPR
 221    PGC    ADVANCE    10,3              CALL DISPATCHER AGAIN    P7.3
 222           TRANSFER   ,PGB                *GPSS OPR
 223    PGG    ADVANCE    20,10             REPEAT MESSAGE COORD     P7.7
 224           TRANSFER   ,PGF                *GPSS OPR
 225    PGAA   ADVANCE    20,10             REPEAT MESSAGE COORD     P7.11
 226           TRANSFER   ,PGAO               *GPSS OPR
 227    PGAC   ADVANCE    120,FN$DIST4      ABNORMAL TRAVEL DELAY    P7.13
 228           TRANSFER   ,DDPGO
        *
        *      *D3 ADVANCED LIFE SUPPORT AVAILABLE
        *
 229    DCO    TRANSFER   .50,PHA,PIA       ADVLIFE SUPPORT AVAIL    D3
```

```
BLOCK                                                                           CARD
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                    NUMBER

        *
        *       *P8.0 BASIC LIFE SUPPORT PROCESS
        *
 230    PHA     ADVANCE    60,30             PATIENT TRIAGE            P8.1
 231            TRANSFER   .20,,PHB          DECISION TO TRANSPORT     D1(P8.0)
 232    PHC     ADVANCE    15,5              TRANSFER TO MED UNIT      P8.3
 233            ADVANCE    15,5              MED UNIT CLEAR SCENE      P8.4
 234    DBPHO   TRANSFER   .20,,PHE          MED UNIT ENROUTE DELAY    D2(P8.0)
 235            ADVANCE    360,FN$DIST1      MED UNIT TRAVEL TIME      P8.6
 236            TRANSFER   .001,,GPSS3       MED UNIT BREAKDOWN        D3(P8.0)
 237    DDPHO   TRANSFER   .10,,PHG          MED FAC ADVISED ARRIVAL   D4(P8.0)
 238            ADVANCE    15,5              OFFLOAD PATIENT           P8.8
 239            ADVANCE    15,5              MED FAC TRANS DELAY       P8.9
 240            LEAVE      AMBU                *GPSS OPR
 241            LEAVE      RAMED               *GPSS OPR
 242            TABULATE   ALSUP               *GPSS STATISTICS
 243            TABULATE   RTIME               *GPSS STATISTICS
 244            TERMINATE                    STOP
 245    PHB     ADVANCE    30,10             UNIT(S) CLEAR THE SCENE   P8.2
 246            LEAVE      RAMED               *GPSS
 247            LEAVE      AMBU                *GPSS
 248            TERMINATE                    STOP
 249    PHE     ADVANCE    120,FN$DIST3      ABNORMAL TRAVEL TIME      P8.5
 250            TRANSFER   ,DBPHO              *GPSS
 251    GPSS3   LEAVE      RAMED               *GPSS
 252            TRANSFER   ,PEBBD              *GPSS
 253    PHG     ADVANCE    30,10             MED FAC PREP DELAY        P8.7
 254            TRANSFER   ,DDPHO              *GPSS
        *
        *       *P9.0 ADVANCED LIFE SUPPORT PROCESS
        *
 255    PIA     ADVANCE    60,30             PATIENT TRIAGE            P9.1
 256            TRANSFER   .20,,PIB          DECISION TO TRANSPORT     D1(P9.0)
 257            TRANSFER   .05,,PHC          MED CONTROL AVAILABLE     D2(P9.0)
 258            TABULATE   ALSUP               *GPSS STATISTICS
 259            ADVANCE    10,5              START ALS STABLIZATION    P9.3
 260            ADVANCE    15,5              ADVISE MED CONTROL        P9.4
 261            ADVANCE    15,5              MED CONTROL DIRECTION     P9.5
 262            ADVANCE    15,5              TRANSFER TO MED UNIT      P9.6
 263            ADVANCE    15,5              MED UNIT CLEAR SCENE      P9.7
 264    DCPIO   TRANSFER   .20,,PIH          MED UNIT ENROUTE DELAY    D3(P9.0)
 265            ADVANCE    360,FN$DIST4      MED UNIT TRAVEL TIME      P9.9
 266            TRANSFER   .001,,GPSS2       MED UNIT BREAKDOWN        D4(P9.0)
 267    DEPIO   TRANSFER   .10,,PIAO         MED FAC ADVISED ARRIVAL   D5(P9.0)
 268            ADVANCE    15,5              OFFLOAD PATIENT           P9.11
 269            ADVANCE    15,5              MED FAC TRANS DELAY       P9.12
 270            LEAVE      AMBU                *GPSS OPR
 271            LEAVE      RAMED               *GPSS OPR
 272            TABULATE   RTIME               *GPSS STATISTICS
 273            TERMINATE                    STOP
 274    PIB     ADVANCE    30,10             UNIT(S) CLEAR THE SCENE   P9.2
 275            LEAVE      RAMED               *GPSS OPR
 276            LEAVE      AMBU                *GPSS OPR
 277            TERMINATE                    STOP
 278    PIH     ADVANCE    120,FN$DIST1      ABNORMAL TRAVEL DELAY     P9.8
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BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS

 279           TRANSFER   ,DCPIO              *GPSS OPR
 280    GPSS2  LEAVE      RAMED               *GPSS OPR
 281           TRANSFER   ,PEBBD              *GPSS OPR
 282    PIAD   ADVANCE    30,10             MED FAC PREP DELAY      P9.10
 283           TRANSFER   ,DEPIO              *GPSS OPR
        *
        *      MODEL SEGMENT 2 (TIMER SEGMENT)
        *
 284           GENERATE   86400             RUN TIME (24 HOURS)
 285           TERMINATE  1                    SHUT OFF
        *
        *
        *      CONTROL CARDS
        *
               START      1
```

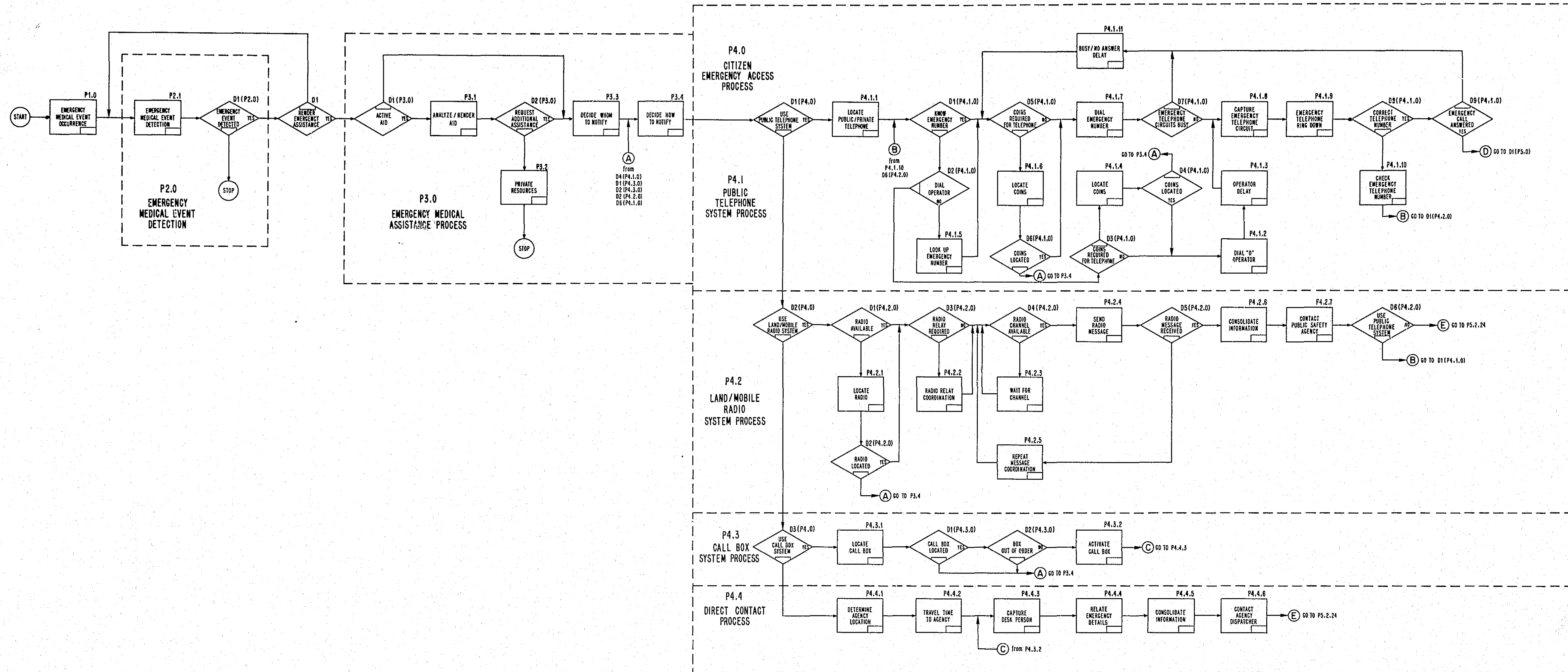
CONTINUED

2 OF 3

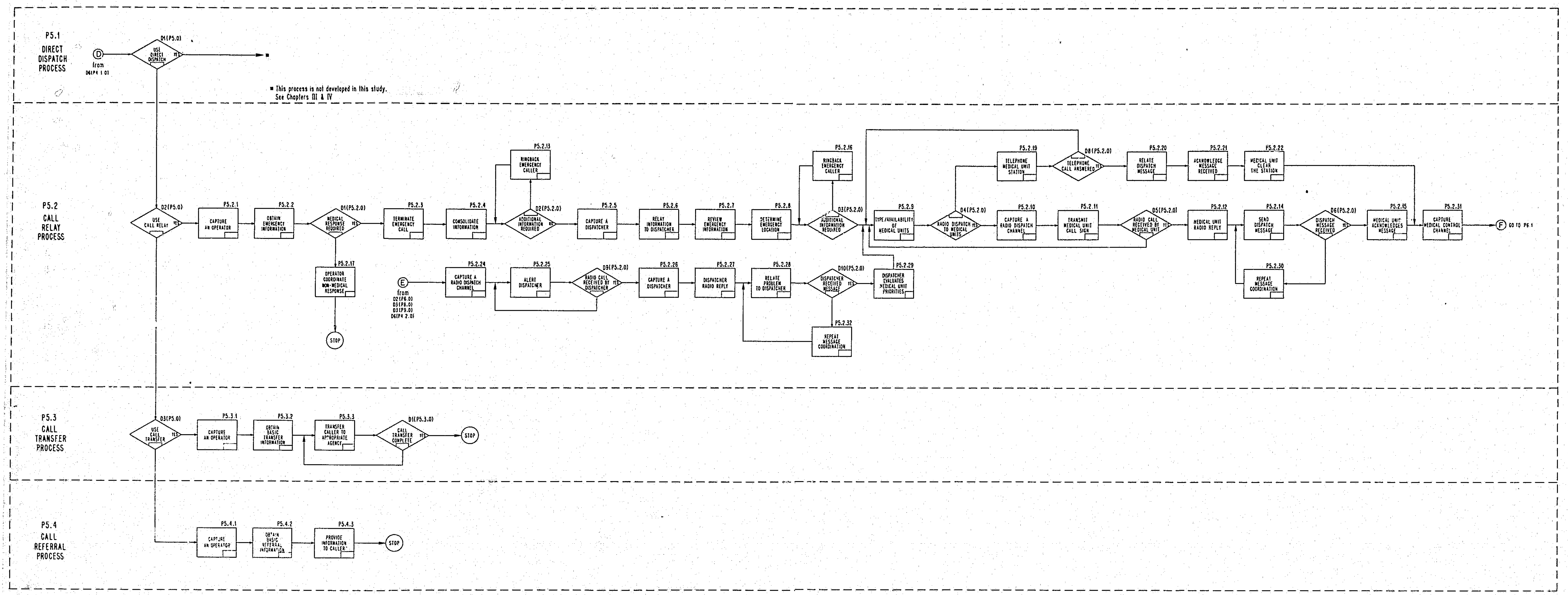
APPENDIX C. ACRONYMS

ALERT	Affiliated League of Emergency Radio Teams
ALS:	Advanced Life Support
BLS:	Basic Life Support
CB:	Citizens Band
EMS:	Emergency Medical Services
FIFO:	First-in First-out
GPSS:	General Purpose Simulation System
LMR:	Land Mobile Radio
PSAP:	Public Safety Answering Point
REACT:	Radio Emergency Associated Citizens Teams
UHF:	Ultra High Frequency

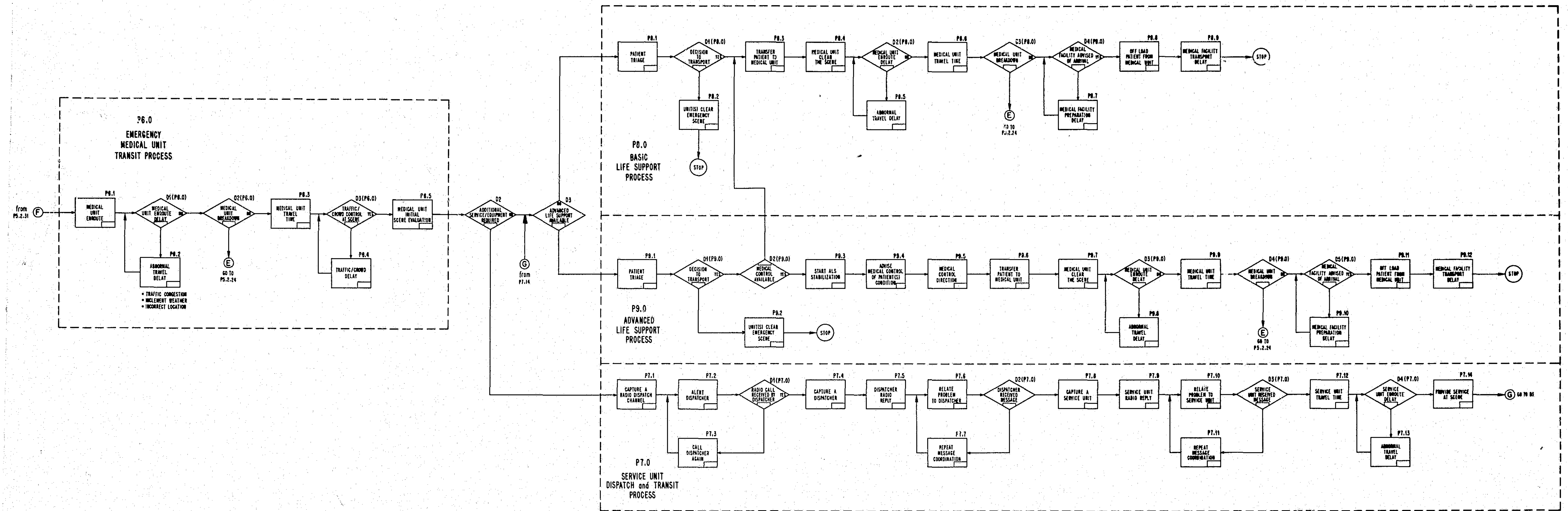
3



4.1 CITIZEN ACCESS PROCESS



4.2 DISPATCH and RESOURCE PROCESS



4.3 MEDICAL PROCESS

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14. SUPPLEMENTARY NOTES

15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This study explores the application of fundamental computer simulation techniques to the planning and evaluation of an emergency medical services (EMS) system. The study is designed to assist local communication managers and planners in designing, modifying and evaluating their EMS telecommunication system to support the goals and objectives of their emergency medical services (EMS) system. This study assumes time to be a critical EMS system variable. The time variable is examined by dividing the EMS system functions into nine major processes. Using flow charts these nine processes are then factored into subprocesses for further analysis. The computer simulation language employed in this model is the General Purpose Simulation System (GPSS). The GPSS is a block-diagram language designed to accommodate the discrete nature of the EMS subprocesses. A minimum of user experience is required to understand and program the model using GPSS. Document includes a significant bibliography.

16. Key Words *(Alphabetical order, separated by semicolons)*

computer simulation modeling; emergency medical communications; land/mobile radio; public safety telecommunications; telecommunications modeling; telecommunications planning.

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