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EUGENE EDGAR PAYNE

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INVESTIGATION AND DEVELOPMENT OF A COMPUTER-ASSISTED

PLANNING MODEL FOR COMMUNITY EMERGENCY CARE SYSTEMS

APPROVED BY

Ray Curl

B L Foote

LaVerne L. Hoag

R A Shapiro

Paul Vargo

DISSERTATION COMMITTEE

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ABSTRACT

In this research the feasibility of developing a computerized planning model of the community emergency care system is investigated. To develop a computerized planning model it is first necessary to derive a definition of the emergency care system (ECS) based upon its functional operating subsystems. A definition is derived and used as a basis for formulating a concise system description. This system description is used, in turn, to develop a planning model.

The technology used in this planning model includes network flow and simulation techniques. A computerized model, the Emergency Care Planning System, is developed and tested with the data from a hypothetical community. There are several unique features in this ECS planning model, however the most significant are a new survival rate evaluation system, and a new method of handling the transportation system.

Survival rate is one of several evaluators that can be used with the computerized planning model devised in this study. In this research a method of representing prognosis curves and

calculating survival rate is developed to facilitate: (1) the input of a variable number of victim categories, (2) the input of new or updated prognosis data, and (3) the calculation of survival rates that are a function of victim category, time, treatment, and treatment time limits.

The transportation system is one of the more important components of the ECS. A method was devised in this research which permits the user to represent the transportation system with the movement of emergency transport units along various transportation networks. The user describes the attributes of both the vehicles and the networks according to the situation that is being investigated. A network optimization subsystem determines the shortest times between any two points in the transportation system along the appropriate network.

The implications of computer solution times for sample test cases (in the areas of data generation, network optimization, and ECS simulation) are discussed.

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CHAPTER I

INTRODUCTION

I.1 The Emergency Care System

Each year 700,000 victims of medical and surgical emergencies die in the United States. [42] The emergency care systems that are established in the various communities to cope with these emergencies are in urgent need of improvement: (a) at the scene, (b) during transportation, and (c) in hospitals. This warning was sounded by the Committee on Acute Medicine of the American Society of Anesthesiologist. [42] They have not been alone in their concern over the status of the community emergency care system.[1] Numerous other organizations and individuals have voiced similar concerns.

In the summer of 1963, following an extensive investigation, the U. S. Department of Transportation reported to Congress that between 10,000 and 20,000 of the more than 50,000 who die each year on the nation's highways might be

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[1] The emergency care system is the system that has been organized in a community for the purpose of saving lives, and decreasing the probability of disabling injuries. [40] It includes transportation, first-aid, and emergency medical care for a victim of an accident or emergency illness.

saved if an adequate, well planned and coordinated, emergency care system were in operation throughout the United States. [81] In addition to a dire lack of ". . . adequate advance planning of emergency communications and transportation," the Department of Transportation pointed out that ambulance services are virtually without regulation or control in most communities. As for the hospital emergency departments it was reported that they are ". . . overcrowded, some are archaic, and there are no completely adequate surveys on which to base requirements for space, equipment, or staffing for present, let alone future needs." [81] Several other studies, such as the one by the Franklin Research Institute,[1] have confirmed these observations.

The present plight of the community emergency care system has been summarized best, perhaps, by R. A. Cowley, M. D., Professor and Head of the Thoracic Surgery Division, University of Maryland School of Medicine. Dr. Cowley reported that:

> Severely injured individuals are constantly present in large general hospitals, particularly those associated with medical schools such as ours. While we do our best to treat these people, many deteriorate and die. Unlike most patients, who are hospitalized for acute or chronic disease

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[1] "No national standards exist for the training or qualifications of ambulance attendants. . . . Most ambulance operations in the United States are unregulated. . . . Planning for community emergency care services is not coordinated." [46, pp. 3/1-3/4]

> and for whom some type of definitive therapy and care is planned, the accident- or emergency ill victim becomes on admission an unwelcome patient since the hospital family is neither prepared nor geared to handle his emergency in a desireable manner. . . .
>
> The public attitude toward trauma is one of indifference because in the experience of the layman the physical injuries that are seen are usually sudden, mutilating, distasteful, gruesome, and indicative of unlikely survival. As a result, to the layman perfunctory treatment is acceptable! Many people are thus allowed to die by general consent since the physician, the hospital and the public have not accepted their responsibilities in trying to improve this desperate situation. [53, pp. 1-2]

These various reports on the status of the emergency care system have made it clear that, despite the sacrifice and diligent efforts of a small group of individuals (both medical and non-medical people), there is an urgent need for improvement of the emergency care system in most communities in the United States. Several authorities have indicated that the root of the difficulties of the community ECS[1] is: (1) insufficient financial support, and (2) lack of thorough community planning, cooperation, and coordination.[2] These authorities point out that the emergency care system is basically a community function, and that the problems of the

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[1]The term "emergency care system" is frequently abbreviated as ECS.

[2]See [42, 53, 51, pp. iv; 46, pp. 1/1-1/2, 3/1-3/4; 81, 85, pp. 35-38].

system must be accepted and solved on a community level.[1] At the present, a true community-level approach to providing emergency care services is not the rule, but the exception. [58, 46, pp. 3/4]

Before a coordinated, well-planned, system for emergency care can be developed the community must meet at least two basic requirements:

1. the establishment of a single, central authority[2] responsible for the planning, coordination, and control of the community ECS, and
2. the development of the ability, of the central authority, to quantitatively investigate and evaluate the community ECS.[3] [39, 46, 86]

Meeting both of these requirements does not quarantee that an adequate, well-planned and coordinated, community ECS will be developed. However, both of these requirements must

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[1]Some authorities feel that the local communities should also be aided by state or federal financial aid and legislation [42, 53, 51, 46, 81, 85].

[2]The central authority could be similar to the city transit authority, or the city zoning commission.

[3]Hyrum Plass, Service to Emergency Patients--Final Report--Phase II--A Program for Study and Action, Reno, Nevada: Bureau of Governmental Research, University of Nevada, 1966, 4-13. See also, Businessweek, Jan. 17, 1970, pp. 50-64.

be met before it is probable that any significant improvement in the community emergency care system will be made.

The first of these requirements--establishing a central authority--is perhaps the most difficult to meet. It involves not only organizational and economic aspects, but also very difficult political and sociological problems. The heart of the problem is the establishment of community[1] acceptance of the responsibility for providing and supporting emergency care on a community level.

Assuming that the community has accepted the responsibility of providing and supporting a community-level ECS, and that a central authority has been established, then the community planners (i.e., the central authority) now have need of the second requirement--an ability to quantitatively investigate and evaluate the emergency care system. This quantitative ability includes: (1) competent professional personnel with capabilities in the areas of systems analysis and medical services, and (2) some basic quantitative techniques, tools, and equipment. Considering only quantitative tools, one tool that would probably be very useful is a computerized planning model of the community ECS.

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[1]The term "community" involves not only the citizens, but also the local government, hospitals, and medical community.

[39, 73, pp. 152-60] The primary purpose of this research is to investigate the feasibility of developing such a tool.

I.2 Purpose of Research

The purpose of this research was to investigate the feasibility of developing a computerized planning model of the community emergency care system. To facilitate this investigation the purpose was segmented into three parts (corresponding to the logical steps in the research):

1. to derive a systems model of the community emergency care system based upon its functional subsystems,
2. to determine evaluators that are probable to be feasible, pertinent, and useful in planning the community ECS,
3. to design and construct a computerized simulation model of the community ECS, based upon a hypothetical emergency care system, that permits the use of the evaluators defined in (2) above.

The very difficult problem of establishing a central authority that is responsible for the community ECS (discussed in the previous section) was beyond the scope of this research. Also, due to the immensity of the project (in addition to the lack of a central authority), it was not feasible to include within the scope of this study the next logical step of this research--a demonstration project.[1] Therefore, this research was directed at a part of only one of the two basic requirements for improving the community emergency care system--the ability to quantitatively investigate and evaluate the community ECS (see Section I.1).

I.3 Simulation Models of the Emergency Care System

In the last decade there have been several significant studies of the community ECS.[2] A few of these were aimed at creating quantitative computerized models. The simulation models that were developed can be generally grouped into two categories:

1. macro models[3] of a disaster or saturated emergency system (e.g., the aftermath of a nuclear attack), and
2. subsystem models of a small, limited part (subsystem) of the total ECS.

Neither of these two classes of simulation models--disaster models and subsystem models--describes the community emergency care system as a total system under normal

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[1] Similar research has indicated that this type of demonstration project requires a large expenditure of funds and manpower [46, 52, 85, 86, 87]. See also, Section V.2.

[2] See the Bibliography under "Medical References" for a partial list.

[3] See Section III.2 for a review of simulation models and terminology.

operating conditions (this was not their purpose). Unfortunately (for community planners), there has been a lack of reported research directed at developing such a model.

To develop a quantitative simulation model of a complex system the relevant components and their general relationships[1] must be identified (i.e., the problem must be stated). To identify the components and relationships that adequately define a process, that is as complex as the emergency care system, usually requires a considerably large research effort. Fortunately, several studies have been performed in the last five years that have been directed at the task of identifying various parts of the general ECS.[2] In Chapter II the results of these studies are used as a basis for defining a systems model of the total community emergency care system in terms of its functional sybsystems. A more concise form of this model, in the form of a system description, is formulated and described in Chapter IV. With this system description available, it was then possible to consider the development of a computerized simulation planning model of the emergency care system. Such a model was devised, and it is discussed in Chapter IV.

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[1]The term "general relationships" refers to what are sometimes called the logical, structural, and sequence relationships. See[26, pp. 189].

[2]These studies are reviewed in Chapter II.

I.4 The Emergency Care Planning System (ECPS)

As a result of this research an experimental computerized planning system, the Emergency Care Planning System, was developed. This sytem is described in Chapter IV.

The Emergency Care Planning System was designed as a planning tool. It was not intended to be a "black box" that could convert a group of input data into a suitable plan for a community emergency care system. It was not meant to replace the judgment or experience of the community planners. Instead, the planning system was designed as a tool that might be used to assist the planners by evaluating the results of various courses of action that were described by the planners. Some of the questions, concerning the ECS, that the planning system was designed to consider were:

1. the effects of changing the level of service in the emergency departments at the various hospitals,
2. the effects of changes in the assignment of medical personnel,
3. the effects of changes in communication systems,
4. the effects of changes in the dispatching of emergency transport units and how the units are equipped and staffed,
5. the effects of changes in traffic patterns, and

6. the effects of changes in various facilities and equipment.

I.5 Summary

The emergency care system is a community responsibility and therefore should be planned, organized, and supported on a community basis. However, due to the numerous complex relationships it is no mean feat for community planners to arrive at the "best" plan for emergency facilities. Unfortunately, there has been little research effort aimed at providing planners with adequate management tools to assist them in this planning. The purpose of this research is to investigate the feasibility of developing one of these management tools--a computerized planning model of the community emergency care system.

CHAPTER II

THE EMERGENCY CARE SYSTEM

II.1 Introduction

In the United States there is not a standard, well-accepted definition of the community emergency care system and its functional subsystems.[1] This lack of a definition is a contributing factor to some of the problems of the ECS. Among other things, the absence of a standard definition makes it difficult to measure performance, to establish state or national operating standards, to promote cooperation in the hospital community, and to coordinate the various functions of the individual community emergency care systems.[2]

Due to natural boundaries, local governments, and various physical limitations it is most appropriate to define the emergency care system in terms of the individual community (city or town). A larger point of view, such as the state or nation, is too large to permit consideration

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[1] Several authorities have proposed definitions. See [47, 52].

[2] See [46, 53, 58, 64, 69, 77].

of sufficient detail (e.g., operating rooms, ambulances, etc.). A smaller point of view, such as an individual hospital in a multi-hospital community, is too small because: (1) it neglects the normally high interaction between hospitals, and (2) it does not adequately permit consideration of various planning strategies for the community (such as pooled resources, or specialized hospitals). In addition, it has also been found that the community point of view is closer to the "real world" situation, and that the local community is the logical basic unit of the ECS. [42, 46] Therefore, since a definition has not been widely accepted, and since the community is the basic unit, the ECS will be defined for the community level.

The emergency care system is that system that exists in a community for the purpose of saving lives and decreasing the probability of disabling injuries. It provides for the transportation, first-aid, and emergency medical care for a victim of an emergency illness or accident. [40]

The following sections will describe the emergency care system in more detail. To facilitate this description it will be advantageous to use two models of the system: (1) a "medical" model, and (2) a more quantitative systems model based upon the functional subsystems of the ECS.

The development of the "functional" model, discussed in this chapter, was the first of the three objectives of this research (see Section I.2). The investigation and determination of appropriate evaluators--the second objective--is also discussed in this chapter.

II.2 Medical Model of the Emergency Care System

This model describes the emergency care system from the viewpoint of numerous knowledgable individuals and organizations in the medical profession. It is principly a subjective description of the system in terms of: purposes, facilities, organization, and operational characteristics. It does not attempt to identify or define the basic functional subsystems or their interactions.[1]

Most medical authorities consider the ECS as consisting of two separate parts, emergency rooms and ambulance service, working together under a community organization. [42] Therefore, the following description of the medical model will be presented in three parts: (1) the community organization, (2) the emergency room, and (3) ambulance service.[2]

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[1] The functional subsystems of the emergency system are considered in Section II.3.

[2] A more detailed description of various parts of the "medical" model are presented in Appendix D.

II.2.1 The Community Organization

According to the American Society of Anesthesiologists, emergency medical care is a community problem. Therefore, it should be evaluated, coordinated, upgraded, and supervised through appropriate "community councils." [42] This council represents the major aspects of emergency service and medical care in the community. One of the functions of the council is organize the community hospital emergency facilities into established categories. The recommended categories are:

Type 1: The First Aid Facility does not have a physician present at all times.

Type 2: The Emergency Hospital is staffed around-the-clock by a physician, but not by a team of specialists and lacks the sophisticated backup facilities of a Type 3 hospital.

Type 3: The Major Emergency Hospital is staffed around-the-clock by a team of specialists available within minutes and will conform to the highest standards hospital-wide and particularly in emergency rooms, resuscitation services, coronary surveillance, and respiratory and general intensive-care facilities. Type 3 hospitals should be established on a regional basis and receive most patients with life-threatening emergencies. Non-life-threatening emergencies may be taken to any hospital with an emergency room. [42, pp. 600]

II.2.2 The Emergency Room

The hospital emergency room is only part of the total emergency care system. However, it is possibly the most important part.[1] The importance of the emergency room to the ECS is perhaps analogous to the importance of the heart in the human circulatory system. The emergency room is also likely to be the most costly part of the system. [86] For these and other reasons, the emergency room has received more attention than the rest of the ECS in medical journals, publications, and research projects.

The following descriptions are based primarily upon the recommendations and standards for the "model" emergency department formulated by the Committee on Trauma, American College of Surgeons [40], and upon recommendations and goals for emergency medical services created by the Committee on Acute Medicine, American Society of Anesthesiologists [42].

II.2.2.1 Function

> The function of an emergency department is to give adequate appraisal and initial treatment or advice to any person who considers himself acutely ill or injured and presents himself at the emergency department door. [40]

This implies that the hospital must not only be prepared to handle cases that medical personnel consider emergent, but also cases that the potential patient considers to be emergent. This definition of the function (objective) of the emergency

---

[1]In a system that is dependent upon many of its components to function at all, it is difficult to determine which component is most important. For example, if a specific organic system requires both a heart and a brain to function, which of these two organs is most important? See [3, pp. 246-57].

department also has important implications for medical care planning, including: (1) if accepted, it means that the hospitals must be aware of the rapidly increasing use of the emergency department and take due consideration of this fact in their immediate and long range planning [40], and (2) while such a subjective non-quantitative definition has some definite advantages (e.g., simplicity, ease of understanding and administering), it will, however, make it difficult to measure the performance of the emergency department (or the community emergency care system).

II.2.2.2 Authority and Direction

> Policy should be formulated and the emergency department should be operated under the auspices of an emergency department committee representing the major medical services and the hospital administration, including nursing service [40].

Also, the department should be supervised by a single director who is responsible only to the emergency department committee. In addition, it has been found that staff morale, quality of service, and public relations are unfavorably affected if the hospital emergency department does not have full department status [41].

II.2.2.3 Personnel

The criterion and guidelines that have been formulated for the staffing of emergency rooms have been primarily of a subjective, nonquantitative nature. Also, the recommendations focus on each individual hospital (they do not normally consider personnel allocation, or assignment, for the entire community as an integrated system). Some of these recommendations include:

> Medical staff coverage should be adequate to insure that an applicant for treatment will be seen by a physician within fifteen minutes after arrival. . . .
> A physician on second call should be available against unexpected or unusual contingencies.
> There should be a mechanism where by specialized medical services can be obtained as promptly as possible when needed. . . .
> The nursing staff should be adequate to handle the average load with provision for additional nursing help during peak hours or unusual circumstances [40].

II.2.2.4 Records

"Every patient should have a permanent record containing the history, findings, and treatment, or disposition [40]." The responsibility for the contents of this record belongs to the attending physician. The hospital should provide a medical record system which includes rapid compilation, central storage, adequate security, and fast retrieval of personal medical records [64, 72, 77].

II.2.2.5 General Policies

The hospital emergency department committee[1] should formulate the general policy for the operation of the emergency department. A few of the recommended policies are listed as follows:

---

[1]See Section II.2.2.2.

> The emergency department should be open twenty-four hours a day. . . .
>
> Every applicant for treatment should be seen by a physician.
>
> The scope of treatment allowed in the emergency department should be specified by the director [with the consent of the emergency department committee]. As a rule, patients requiring general anesthesia should be admitted and treated in the hospital operating suite, and surgical procedures in the emergency department should be limited to the suture of lacerations and the reduction of fractures amenable to local or regional black anesthesia. Serious conditions of acute nature may have resuscitative or supportative treatment started in the emergency department when necessary [40].

II.2.2.6 Facilities

It is a well recognized fact that the optimal facilities for an emergency department will vary not only with geography, but also between various types of institutions [40]. However, a number of valuable guidelines for emergency facilities are still valid [41].

> The emergency department should be located on the ground floor, easily accessible from the main hospital but separated from the main entrance. . . .
>
> The emergency department entrance should be well marked and illuminated, easily accessible from the street, without curbs or platforms, and sufficiently covered and enclosed to protect ambulance patients from the elements during unloading. . . .
>
> There should be waiting rooms, separated from the working area of the emergency department. . . .
>
> Space for stretchers and wheel chairs should be reserved immediately adjacent to the entrance. . . .
>
> X-ray and laboratory services in, or easily accessible to, the emergency department should be available at all times.
>
> Laboratory facilities sufficient for urinanalysis and blood counts should be present in the emergency department [40].

Many organizations and individuals have advocated some form of allocation (and control of allocation) of emergency medical facilities on a community level [46, 53, 58, 79, 80, 86]. However, for all practical purposes, allocation on a community level (based primarily upon actual community needs and resources) has not been attempted or achieved in the United States.

II.2.2.7 Equipment

The equipment in the emergency department should be of the same quality as prevails throughout the hospital [40]. Some of the recommended equipment[1] is listed in Appendix D.

II.2.3 Ambulance Service

There are no national regulations, definitions, or standards for ambulance service. In fact there are seldom rigid standards or regulations on a state or local basis [42, 46, pp. 1/1-1/4]. Several medical authorities have proposed some minimal standards [42, 43, 46, 53, 54, 57, 79, 83, 86, 87, 88, 89]. The most comprehensive are probably those developed by the American Society of Anesthesiologists [42], the American College of Surgeons [88, 89], and the U. S. Department of Transportation [87]. The detailed recommendations of these standards and goals are

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[1]See also, "Emergency Resuscitation Team Manual: A Hospital Plan," (EM 239), Committee on Cardiopulmonary Resuscitation of the American Heart Association, New York: American Heart Association, 1968.

outlined in Appendix D. The general recommendations outlined by the American Society of anesthesiologists are:

> Each ambulance service should have both a physician advisor who is experienced in emergency care and resuscitation and a paramedical supervisor. Minimal training standards and licensure of ambulance personnel should be state-wide. There should be annual inspection of equipment and vehicles.
>
> The driver's ability to drive and the attendant's competence in emergency care should be certified by a licensing authority the employer should be accountable for the character and moral conduct of those whom he employs. . . .
>
> In addition to the driver, there should be at least one, preferably two attendants with the patient in the ambulance.
>
> Ideally, emergency transportation should be restricted to full-time licensed ambulance personnel, which has proved feasible in urban centers. In rural areas training of the presently prevalent part-time ambulance attendants should be upgraded. The training in acute medicine of paramedical technicians who would serve as helpers in emergency rooms, intensive care units, and inhalation therapy departments, and who should staff hospital-based ambulances when needed should be thoroughly investigated [42].

II.3 Functional Model of the Emergency Care System

Until the 1960's there had been a lack of published research directed at defining a general systems model of the community emergency care system based upon its functional subsystems operating under normal conditions.[1] However, several recent studies have attempted, in varying degrees, to define the system [46, 47, 48, 64]. The most

---

[1] The community ECS system had previously been defined normally in non-quantitative (often intuitive) terms. The major functional subsystems had not been explicitly described.

comprehensive model was developed by Bordner, et al. [46], at the Franklin Research Institute in a study sponsored by the U. S. Department of Transportation. Although the emergency care system as defined in this chapter differs in some respects, it is nevertheless generally based upon the findings of the Franklin Institute study. The model is presented in terms of the functional subsystems of the general emergency care system.

II.3.1 The Emergency Care Cycle

Before describing the functional model of the ECS it will be useful to first consider the actual operational cycle of emergency care. The emergency care cycle is outlined in Figure 1 and Table 1. Figure 1 illustrates the general flow of events that transpire during the use of the community emergency care system. The functional subsystems that compose the ECS must work together to satisfy the requirements of this operational cycle [46, pp. 2/1-2/3].

II.3.2 Subsystems of the Functional ECS Model

The emergency care system is composed of several smaller subsystems. These functional subsystems work together to provide the total system responses necessary to meet the requirements of the operational cycle. The subsystems are: communication, transportation, medical treatment, and documentation [46, pp. 2/2]. The totality of these subsystems (and their respective smaller modules)

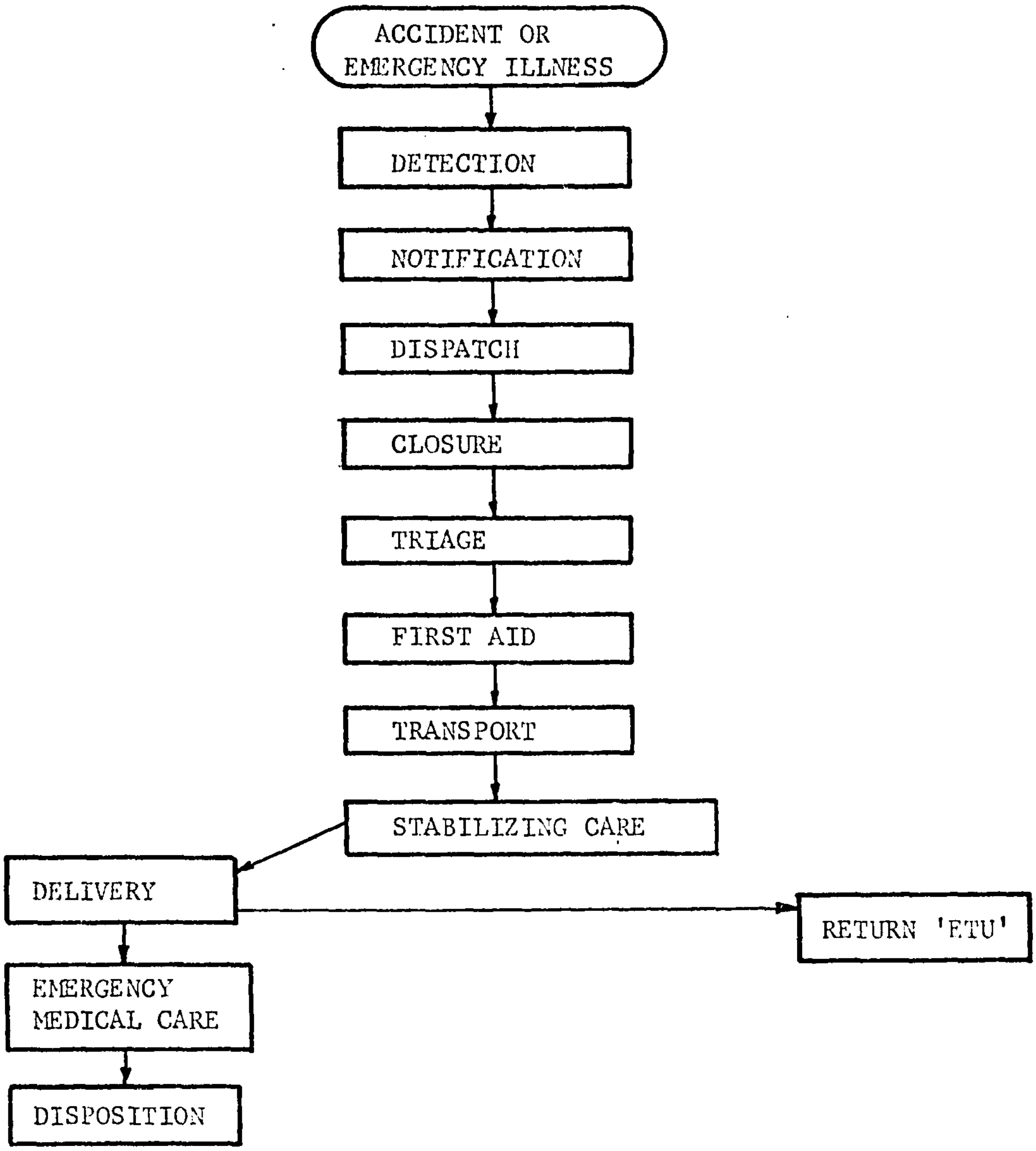

Figure II.1 The Operating Cycle of Emergency Care [47].

TABLE II.1--Definitions

	Terms used in the Emergency Care Cycle
Detection	the accident or emergency illness is discovered
Notification	the accident is reported to the emergency service dispatcher
Dispatch	the appropriate emergency service unit is dispatched
Closure	the emergency unit locates and closes onto the scene
Triage	predetermined priorities are used to determine the order of care and treatment of victims
First Aid	initial care is given and the victim's condition is stabilized
Transport	the victim is moved to the location where medical care is available
Stabilizing Care	care is rendered (during transport) to maintain stability of victim's life functions
Delivery	victim is transferred from the care of the emergency unit to the emergency room
Disposition	the victim is moved within the hospital to the proper care facility other than the emergency room
Emergency Medical Care	the victim is given emergency care by a professional medical person
Return ETU	the emergency transport unit returns to its proper station, ready for another call
ETU	Emergency Transport Unit (e.g., ambulance)
	Other Terms
Prognosis Curve	an estimate of the probability of death associated with an injury as a function of elapsed time

TABLE II.1--Continued

	Other Terms
Response Time	elapsed time required to deliver help after assistance has been requested
Definitive Medical Care	hospitalization (if necessary), and medical care, capable of caring for patients until they recover
Emergency Room	that physical facility which is a special service area of a general hospital and which is specially equipped and staffed to treat traumatic and other types of medical conditions that are felt by either the patient, his doctor or the agency transporting the patient to the hospital, to be in need of immediate professional attention[1]
Emergent	the condition of a patient that requires immediate medical attention; time delay is harmful; hospitalization is probable
Urgent	the condition of a patient that requires medical attention within a few hours: there is a possible danger to health if untreated; alleviation of severe pain often the immediate primary consideration
Non-urgent	the condition of a patient that does not require medical attention within a few hours to prevent harm to health (i.e., does not require emergency service); routine medical care may or may not be needed

[1] J. L. Miller, Patterns of Emergency Room Utilization in San Luis Obispo County, California, Washington, D. C.: George Washington University, 1966.

defines the general emergency care system.

II.3.2.1 Communication Subsystem

The communication subsystem must provide the means for summoning initial aid to the victim, provide medical support (information) for stabilizing care, and facilitate proper utilization and coordination of emergency medical resources. More specifically, it must:

1. provide a procedure for proper handling of incoming calls for emergency assistance (screening, establishing priorities and allocating emergency units), and
2. provide a means of communication between the dispatcher, emergency rooms and emergency service units (e.g., ambulances) for the purpose of receiving medical instructions (at the scene and enroute), updating victim status, warning emergency room of pending arrival, and securing additional emergency assistance.

Considering the various requirements, it is possible to define the unique events of the communications subsystems [47]. Any use of the communications subsystem will involve one or more of the following events.

Event	Description
C(1)	detection of a need for assistance
C(2)	notification of the need to the dispatcher
C(3)	determining proper allocation of emergency units
C(4)	dispatching emergency service units
C(5)	communication enroute to scene between emergency unit, dispatcher and emergency room
C(6)	communication at the scene
C(7)	communication enroute to emergency room
C(8)	request for additional emergency assistance
C(9)	notification to dispatcher of completion of task by emergency unit

II.3.2.2 Transportation Subsystem

The transportation subsystem must provide a means of bringing together the victim and the medical resources required for treatment. This purpose can be accomplished in a number of ways. The two "pure" strategies [38] of accomplishing this are: (1) move the victim to all of the medical resources, or (2) move all the medical resources to the victim. There are, of course, numerous "mixed" strategies [38] between these two extremes. For example, administering some elementary medical care at the scene and then transporting the victim to an emergency room is a mixed strategy. The events which define the transportation subsystem must be able to describe all possible relevant strategies. These events are listed as follows:

Event	Description
T(1)	movement of the emergency unit to the scene
T(2)	movement of the victim into the emergency unit
T(3)	movement of the emergency unit to the emergency room
T(4)	movement of the victim into the emergency room
T(5)*	movement of the victim within the hospital to the proper medical facility (assisting medical treatment in disposition)
T(6)	movement of emergency unit to its waiting station

---

*This event is often done in conjunction with event M(6) (see Section II.3.2.3).

II.3.2.3 Medical Treatment Subsystem

The medical treatment subsystem provides the first three levels of medical care to emergency victims [47, 42, 52, 53, 74]. These levels are:

1. First Aid -- initial elementary medical care given to the victim to bring about stability of the life functions and prevent or arrest further injury or deterioration of condition (professional medical skill not required),
2. Stabilizing Care -- continuation of First Aid to continue stability of victim's condition until professional medical care is available, and
3. Emergency Medical Care -- an emergency procedure performed in an emergency room, or before

arrival at an emergency room, by a physician, or equivalent medical professional, but is not strictly definitive medical care (see Table 1).

Definitive medical care is not included in the subsystem, because, in a strict sense, it is not a part of the emergency care system as the system has been defined.[1] The events of the medical treatment subsystem are listed below:

Event	Description
M(1)	triage -- the sorting of injuries and victims into categories for order of treatment according to predetermined priorities
M(2)	first aid
M(3)	stabilizing care
M(4)	transition -- passing the responsibility for care of the victim from the emergency unit to the physician in emergency room
M(5)	emergency medical care
M(6)	movement of the victim to the proper section of the hospital other than the emergency room[2]

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[1]Under the above definitions it is possible for some professional medical care to be both emergency and definitive (e.g., the removal of numerous cactus needles from a child's hand). However, strictly definitive medical care, that is not emergency, is not included in the emergency care system (some hospitals do permit it to be practiced in the emergency room). In this research, definitive medical care is defined as hospitalization (if necessary), and medical care, capable of caring for patients until they recover.

[2]An emergency victim is not always treated in the emergency room of the hospital. It may be necessary or advisable to move the victim to some other section, such as the operating suite or X-ray lab. However, this movement frequently requires some resources of the ECS, such as a nurse, ambulance attendant, etc.

II.3.2.4 Information Subsystem

The emergency information subsystem provides for the collection, use, and analysis of data associated with emergency accidents or illness inclusive of the time of the accident until dismissal from the emergency room. Data are collected and information derived for two primary purposes:

1. patient treatment -- the quality (appropriateness) of the medical treatment received is often dependent upon the physician having access to correct information about the victims' accident/illness, first aid rendered, and the recent course of his conditions and life functions, and
2. statistical analysis -- statistical analysis of past cases, treatment, and resource utilization is of paramount importance both in determining the best allocation of emergency resources, and in improving medical care by an analyzing the results of different medical treatments.

The events in the information subsystem are listed below.

Event	Description
I(1)	recording dispatch -- recording the time an emergency unit was requested, when it was dispatched, where it was sent, the emergency unit identification, what type of emergency and source of request
I(2)	recording first aid -- recording initial condition of victim, time and type of first aid rendered

Event	Description
I(3)	recording stabilizing care -- recording progress of the condition of the victim and care rendered
I(4)	debriefing -- oral debriefing of emergency unit crew by emergency room personnel[1]
I(5)	assisted debriefing -- oral debriefing is assisted by reference to written emergency unit record[1]
I(6)	release -- emergency unit is given formal (written) release by emergency room (can be a part of emergency unit record, if one is kept)
I(7)	transition of ETU record -- copy of emergency transport unit record on victim (if there is one) is transferred to emergency room record on victim [49]
I(8)	ER record -- treatment and condition of victim is recorded on patient's emergency room record
I(9)	record collection -- emergency room record is collected (by medical records section) after patient leaves emergency room. Copy of pertinent data (no name or patient identification) is sent to Emergency Analysis Information System (EAIS).[2] If patient remains in hospital the emergency room record is entered into his chart, otherwise his record is filed in the hospital central medical records file.

II.4 Important Concepts

To enhance the description of the functional model it is useful to consider in more detail two of the concepts defined in Table 1.

II.4.1 Prognosis Curves

A prognosis curve indicates the probability of death from a specific injury or illness, as a function of time and

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[1]Events I(4) and I(5) are exclusive events. They represent two different means of debriefing.

[2]See [46, 53].

care received. If it were possible to determine these curves exactly it is probable that they would not be linear. However, to date, most estimates of prognosis curves have assumed some form of linearity as a simplifying measure.[1] The curves are usually defined for various levels of medical care (physician, paramedical personnel, self-help, no treatment, etc.). The general form of prognosis curves is indicated in Figure 2 and Figure 3.

II.4.2 Triage

Triage is an essential part of the medical treatment system. As used in this research, it has two aspects:

1. if a victim has multiple injuries, triage specifies the order in injuries are to be treated, and
2. if there are multiple victims, triage determines the order in which victims are to be treated.

The basic objective of triage is normally to maximize the survival rate (and/or minimize rate of disabling injuries). There are numerous strategies that might be employed to attempt to "optimize" this objective [52, 84, 74].

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[1] To simplify the curves, often a double plateau curve is assumed (triple plateau curve in Figure 2). Also, treatments levels are often assumed to have the same slope, but with mortality reduced a constant amount. See [74, 52, 80].

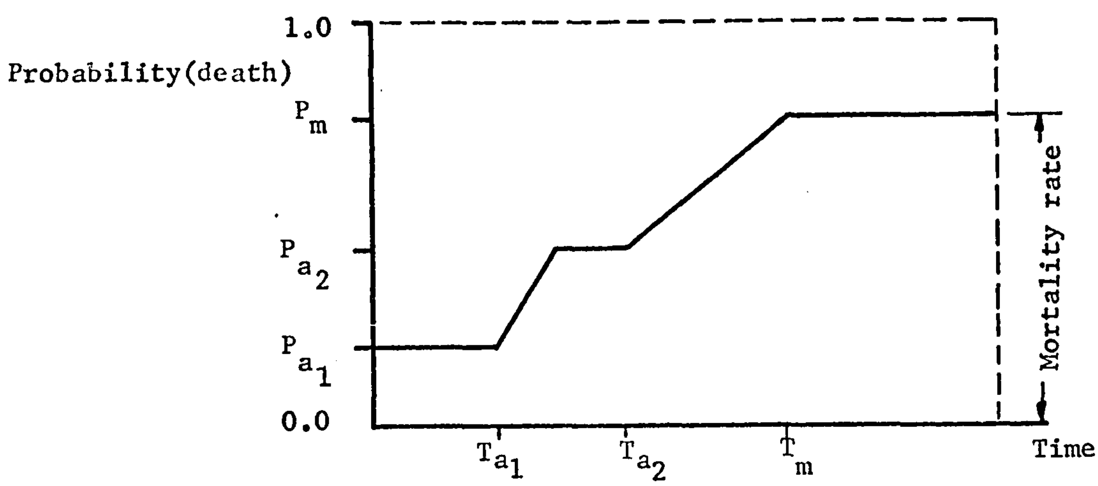

Figure II.2 Prognosis Curve for No Treatment

P_i = probability of death at the occurrence of the injury/illness

P_{a_i} = probability of death during the *i* plateau (in the above case $P_1 = P_{a_1}$)

P_m = maximum probability of death within the total time scope being considered (S or T_s)

T_{a_i} = amount of time that can elapse before a delay in treatment affects the probability of survival

T_m = time beyond which treatment does not alter P(death)

T_s = time scope of consideration

T_t = time treatment begins

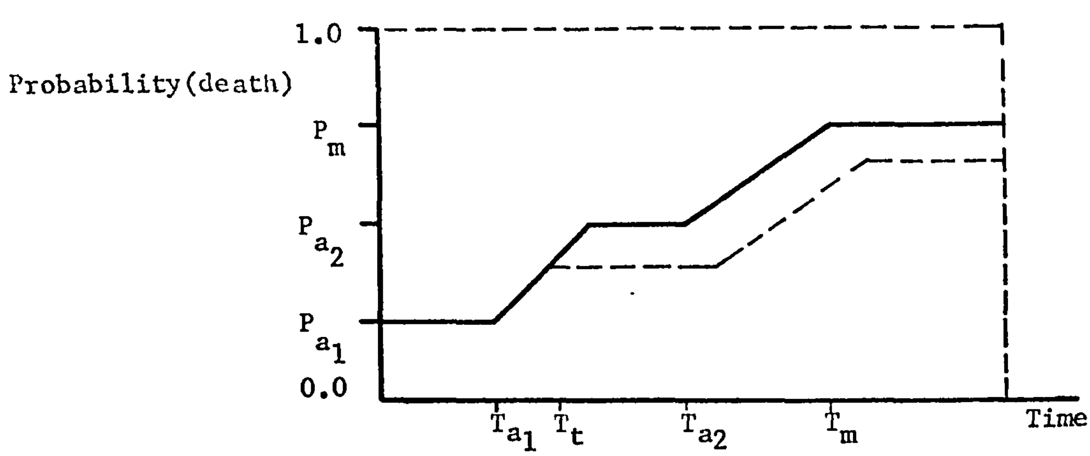

Figure II.3 Prognosis Curve for No Treatment and Paramedical Treatment

In actual medical situations triage is practiced by medical personnel by assuming some prognosis curves for the victims and assigning priority for treatment so as to maximize the survival rate. The curves used by the medical personnel are not actually formalized. They are usually a subjective understanding of the pathogenesis of patient's condition, based upon the physician's medical experience and knowledge.

II.5 Evaluators to Measure the Effectiveness of the ECS

An investigation of published research revealed that there are numerous criterion that have been used, or proposed, to quantitatively measure the effectiveness of the emergency care system. These evaluators generally fall into the following categories:

1. response time -- the total lapsed time required to respond to a call for help [43, 41, 60],
2. survival rate -- a statistical measure of survival for various types of injury or illness (and/or rate of disablement of victims) [46, 52, 74],
3. level of care -- a measure comparing the level of professional medical care received versus the level of professional medical care appropriate for various types of injury or illness [46, 52, 56, 66, 75,

86],

4. cost -- cost of providing care [46, 56, 60, 79, 86].

All of these criterion have proponents. However, the most appropriate (and important) are survival rate and cost. Cost is important because money is a scarce resource no matter how humanitarian the objectives.[1] Therefore, it is uaually necessary to determine the best system that can be constructed within the cost limitations.

Survival is the primary purpose of the emergency care system (not necessarily the only purpose). Therefore, survival rate is the best measure of how well the ECS is functioning [73, 80]. However, the survival rate criterion has serious drawbacks. First, community emergency care systems today have not been designed to acquire the data necessary to measure this criterion. Second, there has been little basic research in determining prognosis curves. These curves are necessary to evaluate proposed changes in the ECS if the survival rate criterion is to be used. A similar problem exists in using the level of care criterion.

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[1]The objective of the ECS is certainly humanitarian. One way a community could come closer to meeting the objective of their ECS would be to build an emergency room facility every 100 yards on every mile of road within the community. Although, intuitively one would be inclined to agree that this would improve the survival rate, the proposal is obviously impossible for virtually any community because of the extreme cost involved (even assuming availability of medical resources and neglecting effects on the rest of the medical care system).

To use the level of care criterion there must be an optimal or best level of professional medical care determined for the various types of injury or illness.[1] There has been only limited research performed to attempt to determine these levels. Adequate research would require basic medical treatment research aided by an extensive data collection system and statistical analysis. At the present, due to the lack of research, the best way to determine levels of care is probably by using a professional medical panel [74, 52, 80]. However, using this method the levels of care recommended would be based upon subjective decision. A criterion that perhaps appears to be more objective is response time.

Response time has received support as the best, presently available, measure of effectiveness from several sources [79, 46, pp. 1/2].

> The concept of "improved ambulance service" can be described quantitatively by two related performance measures: (1) response time -- the period between receipt of a call at the ambulance station and arrival of an ambulance at the scene; (2) round-trip time -- the period between receipt of a call at an ambulance station and arrival of the assigned ambulance at the hospital with the patient. . . . a decrease in response time produces the same reduction [as] in round-trip time. . . . Effectiveness was measured in minutes of average response time and also in the percentage of calls whose response time exceeded a certain

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[1]Although level of care, as used here, refers to the background, experience, and speciality of the medical personnel, it could be expanded to encompass the medical treatment or procedure.

level [79, pp. B602].

> Conclusion: Emergency care systems demonstration projects are not amenable to the normal techniques for program evaluation. Recommendation: Until such time as a valid measuring technique can be developed for the relationship between emergency treatment applied and the resulting degree of death and/or disabling injury, demonstration projects should be confined to areas where system improvements can be measured by a reduction in system response time [46, pp. 3/4].

The basic support of the response time criterion appears to be based upon two facts: (1) response time can be readily measured, and (2) although prognosis curves may not be known, intuition tells one that mortality of injury is a function of response time.[1]

All of these criterion, that have been described, are valid under various conditions. The best design for a system to measure the effectiveness of the ECS would probably include all of these criterion. This would present the maximum relevant information upon which to base a judgment of the effectiveness of a specific plan for a community emergency care system.

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[1]The author feels that survival rate (although more difficult to use) is a better criterion than response time because: (1) response time actually makes an assumption of a general prognosis curve by its "intuitive" relationship of mortality as a function of elapsed time, (2) survival rate forces one to state quantitatively this relationship between mortality and elapsed time (this is the only way the accuracy of the relationship can be judged and improved), and (3) although survival rate may be more difficult to use, this is more than compensated for by the increased sensitivity of the user, due to its use.

CHAPTER III

APPLICATIONS OF SIMULATION TECHNOLOGY TO THE EMERGENCY CARE SYSTEM

III.1 Introduction

In Chapter II a "functional" model of the community emergency care system was developed. Chapter IV will describe how this model was used to formulate a concise systems description, and to design a computerized planning system based upon simulation techniques. Therefore, as a basis for this discussion of the planning model, it is useful at this point to review the applications of simulation technology to the area of the emergency care system.

III.2 Simulation Models of the ECS

Over the last decade there have been a number of research efforts directed at formulating simulation models of various portions of the medical care system in the United States.[1] Several of these models were reported to have been useful tools in answering both planning and operational questions. However, in the area of the emergency care

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[1] Some examples are described in [39, 45, 52, 59, 60, 73, 79, 80, 85].

systems there has been research in only a few special areas that has attempted to develop simulation models.

Simulation models that have been developed in the area of the ECS generally fall into one of two categories: (1) subsystem models of a small, limited part of the total ECS, and (2) disaster models. Unfortunately, there has been no reported attempt to construct a simulation planning model of the total community emergency care system, under normal operating conditions. However, since they are related to the community ECS, it will be useful to review the two categories of models on which research has been performed. To facilitate this review, simulation terminology will be discussed first.

III.2.1 Review of Simulation Models and Terminology

In basic terms simulation has been defined as follows:

> Simulation involves the representation of a system by a new system which purports to have a relevant behavioral similarity to the original system. The simulator is usually simpler than the system being simulated, and is more tractable to manipulation and analysis [73, pp. 24].

Simulation usually requires the construction of a working mathematical, statistical, or physical model which represents the similarities of the properties or relationships of the natural system under study.[1] According to Mize and

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[1] This review of simulation is based upon the review of the subject in [20, 25, 26, 28].

Cox [26] a simulation of a system is used in lieu of either: (1) direct experimentation with the system itself, or (2) direct analytical solution of some problem associated with the system.

There are numerous ways to describe the models that are used to simulate a process. Perhaps the clearest method of describing these models is to refer to them according to: (1) classification of model (classifications are general descriptors of systems analysis models), (2) type of simulation model, and (3) level of detail.

III.2.1.1 Classification of Models

According to Naylor, et al. [28] system analysis models (simulation and other types of models) can be classified as deterministic, stochastic, static, dynamic, mathematical, and flow. These classifications, which are not mutually exclusive, may be described more specifically as:

1. deterministic -- the variables and parameters[1] of the model are not allowed to be random, and the mathematical relationships are exact,
2. stochastic -- one or more of the variables or parameters are defined by a probability

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[1]A parameter is an attribute of the system that does not change in value during the course of the simulation, unless altered by the experimenter. A variable is an attribute that normally may take on different values under different conditions during the simulation.

distribution function,

3. static -- variable time is not considered in the model,

4. dynamic -- variable time is considered in the model,

5. mathematical -- the variables and parameters are stated in exact mathematical terms and relationships, and the flow of events is of little or no importance,

6. flow -- although there might be numerous mathematical relationships explicitly stated, the sequence of events is of primary importance.

Another term, "Monte Carlo," is often encountered in the literature as a sort of classification of models. However, Monte Carlo actually refers to a device or method that is used when studying a stochastic process [73]. In loosest sense, "Monte Carlo" and stochastic" might be used interchangeably.

III.2.1.2 "Types" of Simulation Models

There are many types of simulation, however, this research will be concerned only with those types that are computer assisted. There are basically four types of computer assisted simulation models: one-to-one, gaming, game-simulation, and all-computer simulation [73, pp. 14-19].

These types are not exclusive (i.e., a model could conceivably be described as being a combination of several "types"). The characteristics of these models are outlined in Table III.1.

III.2.1.3 Level of Detail

The "level of detail" is often used to describe a simulation model [73, pp. 4]. There are basically three levels of detail:

1. micro -- virtually all of the relevant details of the actual process being simulated are included in the model in minute detail (example: an aircraft simulator for training pilots),
2. macro -- only the major parts of the process are included in the model, and normally only in aggregate terms (example: an economic model of the United States, such as the Wharton model created at the University of Pennsylvania), and
3. intermediate -- not as aggregate as the macro, but not as detailed as the micro model (example: models used by middle management in industry, such as inventory models).

III.2.2 Subsystem Models of the Emergency Care System

The design and construction of a few subsystem models in the area of the community emergency care system

TABLE III.1--Types of Simulation Models

	One-To-One	Game	Game-Simulation	All-Computer Simulation
Description	used for training --example is aircraft simulator for pilot instruction--skills are acquired in handling system simulated	result of game not usually important -- education and insight of player important--example is war game or business game	interested in answers about effects of various policies or modifications to the system--interaction between computer and man	simulation is represented entirely by computer (all decisions must be specified)--interested in specific questions about the system (similar to Game -Simulation, but removes the man)
Objectives of Model	training and education -- acquire skill	insight and education -- learn tactics	investigate policies and feasibility	quantitative answers to specific questions - also, investigate policies
Role of Players	trainee	trainee or researcher	integral part of study	usually none
Level of Detail, and Specification of Process Steps	very detailed -- specification loose -- (micro) little or none	broad and aggregate detail--specification loose--(intermediate to macro) little or none	usually more detailed than Game model -- more highly specified (micro to intermediate)attempt at quantification	all decisions completely specified and detail varies -- (micro to macro) quantitative and formal
Time Compression	none or low	high	low	very high
Cost	high	low	very high	medium

have been reported.[1] These are usually all-computer models, on a micro or intermediate scale, that consider only a small, limited part of the total ECS. Their purpose is normally to investigate a few, very specific, operational and planning questions. One recent model, that was reported to have been very useful, is one that simulated limited portions of the New York City ambulance service [79].

The purpose of the New York model was stated as ". . . to analyze the possible improvements in ambulance service that would result from proposed changes in the number and location [of ambulances] [79, pp. B600]." In this special purpose model the measure of effectiveness was response time of the ambulances. The primary question that was investigated was the advisability of dispersing ambulances at various "waiting stations" rather than concentrate them at a central station. The dispersement strategy was found to be significantly more effectively in reducing response time (with little or no increase in cost).

Another recent subsystem model investigated the admissions system in the emergency room. Data collected for use in the model included: time of patient arrival, mode of arrival, hospital services used, various waiting and treatment times, lengths of stay, utilization of laboratory, and discharges [45]. The model was used to investigate the effects of various operational policies.

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[1] See [45, 59, 39, 79].

III.2.3 Disaster Models

Disaster models constitute the preponderance of research in the application of simulation technology to the area of emergency care systems. The purpose of these various macro models is usually to: (1) formulate a disaster plan for a community, or (2) to function as a disaster training tool for medical systems administrators. The disaster that is normally of paramount consideration is a nuclear attack.

By their nature these models do not consider the community emergency care system under its normal operating conditions. In fact, large parts of the system are usually considered non-operational (destroyed). Also, since there are more casualties (by several orders of magnitude) the measurements made in the disaster models are more aggregate than would be appropriate if the normal operating conditions were being examined and evaluated.[1] Although these models do consider a different type of emergency system than has been defined for this research, since the disaster models do make some valuable contributions necessary for construction of the community ECS model, two of the most comprehensive disaster models are reviewed as follows.

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[1]If one is measuring the length of a battleship, then a millimeter more or less is immaterial (contraction and expansion alone may be in centimeters). However, if one is measuring electronic components for the battleship gyroscope, then a millimeter is significant.

III.2.3.1 Research Triangle Disaster Model [52]

The purpose of this model is to measure the effectiveness of alternative disaster (medical) support systems in the immediate period following a nuclear attack. Effectiveness is measured by the survival rate. All of the elements of the disaster support system are described in the model. Inputs to the model are: personnel, facilities, supplies, casualty list, prognosis curves, and triage rules. Output is the survival rate.

The model was used to investigate both the result from varying medical resources (personnel, facilities, supplies, etc.) and the result of warning or not warning the population. The model was concluded to be a useful tool in evaluating plans for nuclear disaster [52].

The most important contribution of this model, in the view of the research considered in this project (model of community ECS), was the development of a type of prognosis curves. Although these curves were developed for aggregate measures in a disaster situation (with large numbers of casualities), they are still useful as a general guide for the development of appropriate curves for use under normal operating conditions.

III.2.3.2 Texas Hospital Association Disaster Model [80]

The T.H.S. model is similar to the Research Triangle model. They have virtually the same purpose -- " . . . the study of resource allocation in a potential disaster locality and for the training of disaster managers [80, pp. ii]." The major differences between the two are: (1) the philosophy of triage used, (2) details of various sub-parts of the models, and (3) method of implementation of the models. The most important contribution of the T.H.A. model, in the view of this research project, is the development of relatively detailed prognosis curves.

Death and recovery of the injured are described by class and level of care. This description is in terms of medical treatment personnel, medical supplies, and medical facilities available for the treatment of the injured as a function of time.[1] These data and curves were developed under the direction of W. S. Moore, M.D., Texas Hospital Association. The details of these curves are presented in Appendix C.

III.3 Summary

There have been a few simulation models designed and constructed in the area of emergency care systems. The models have generally been of two types: (1) subsystem models of a few small, limited parts of the total ECS, and (2) macro disaster models considering aggregate measures and problems of the emergency facilities in the wake of a

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[1]L. H. Williams and W. C. Richie, "A Disaster Environment Simulator," Simulation, September, 1969.

massive environmental upheaval (e.g., nuclear attack). Despite the need for such a tool by community planners, there are no published reports of research aimed at development of a quantitative planning model (e.g., simulation model) of the ECS under normal operating conditions.

As revealed in this chapter and in Chapter II, in the last few years several research studies have uncovered the information necessary to identify the basic relationships in the general emergency care system. This information now makes it possible to attempt the formulation of planning models of the ECS utilizing simulation technology.

CHAPTER IV

PLANNING MODEL OF THE EMERGENCY CARE SYSTEM

IV.1 Introduction

A functional systems model and the evaluators of the emergency care system were presented in Chapter II. That system's model will be restated here, in the initial sections of this chapter, in the form of a systems description. This system description was developed in terms that were convenient for describing mathematical and logical computerized models and their quantitative evaluators. The remainder of this chapter will be devoted primarily to describing various aspects of a computerized planning model, the Emergency Care Planning System, that was developed in this research.

IV.2 System Description of the Emergency Care System

A model based upon the operating functional subsystems of the emergency care system was presented in Chapter II. This type of model is very helpful in defining and understanding a complex system such as the ECS. However, to construct a mathematical and logical computerized model it is necessary to describe the system in the more concise form of a system description [26].

The system description of the ECS that was developed had five primary features: (1) objective and evaluation, (2) components, (3) variables, (4) parameters, and (5) relationships.[1] The details of this description are incorporated in the actual computerized planning model --the Emergency Care Planning System.[2]

A general, non-detailed outline of this system description is presented below.

1. Objective and Evaluators. The objective and evaluators are statements describing how the results (endogenous variables) will be evaluated. The objective of the ECPS[3] model was to permit the measurement of the change of several evaluators that resulted from some arbitrary change in the system. The evaluators, as discussed in Section II.5, are:

    a) Response time - the time to respond to an emergency call,

    b) Survival rate - a statistical measure of survival probability for given classes

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[1] For a discussion of the nominal features of a system description, see [26, 28].

[2] Payne, E. E., ECPS Systems Manual. Industrial Engineering School, University of Oklahoma, 1970.

[3] Emergency Care Planning System.

of injuries or illnesses,

c) Level of care - a measure of the level of professional medical care received for each class of injury or illness, and

d) Cost - cost of providing care.[1]

The use of one of these evaluators, survival rate, requires the user to present meaningful data on both the classification of injuries and prognosis curves. A method will be presented in Section IV.4 that was devised in this research for using these prognosis data when they are available.

2. Components. These are the entities of the system that work together to provide the total system response. For the ECS there were a large number of components identified. However, only those components that comprised the normal operating system, and

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[1]As discussed in Section II.5, there are many various cost that could be associated with the emergency care system (e.g., cost of medical care, social cost, opportunity cost of a patient missing work, and so forth). However, the only cost that is being considered in this research is the direct cost that an organization would incur if it were providing the emergency care system for a community. Also, in a specific analysis of alternatives for the ECS, normally only the "controllable" cost for the allowable alternatives are considered. See R. N. Anthony, Management Accounting. Homewood, Illinois: Irwin Inc., 1964, 394-442.

that appeared to have a substantial measureable effect on the evaluators were considered. The categories of the major components identified were:

a) the victim

b) the emergency transport unit

c) the emergency room

d) the medical personnel

e) the transportation network

f) the communication network

3. Variables. Variables are attributes of the system that may take on different values under different conditions.[1] Some of the more general variables that were pertinent to the evaluators were:

a) ETUs in available status

b) location of ETUs

c) communication system availability

d) emergency rooms availability

e) availability of equipment, supplies, and personnel

f) victims (number, type, location, time, medical preferences)

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[1]Variables may be described as: independent or dependent; controllable or non-controllable; internal or external; input or output [26].

g) treatment times

h) response times

i) survival rates

4. Parameters. These are attributes of the system that do not change during the course of the simulation, unless altered by the experimenter. The value of the parameters can only be changed during the simulation, or prior to it, at the command of the experimenter. However, this definition may also describe a variable that is independent, controllable, external, and input. It is possible to define the slight difference between this type of variable and a parameter; however, that was not done. For simplicity, the type of variable just described was considered to be only a parameter. The principal parameters that were developed were:

   a) binary logic keys (e.g., do or do not calculate survival rate; do or do not give first aid to all victims at the scene by ETU personnel prior to transit of own patients; do or do not use victim emergency preferences; do or do not let the dispatcher make emergency room assignments)

   b) medical data (prognosis curves, victim categories, effect of treatment on prognosis curves)

c) emergency transport units (capacity, personnel, type equipment)

d) emergency rooms (equipment types, medical personnel available)

e) dispatching (central or regional, times and delays required)

f) transportation network (number of nodes arc travel times, air or surface, effect of hour of day on network)

g) assignment logic (penalty functions for assignment of ETU and ER to a victim)

h) time scope of simulation

5. <u>Relationships</u>. Relationships describe how the components, variable, and parameters are connected to each other in the model. Relationships may be structural, functional, or sequential [26, p. 144-5]. The principle categories of the relationships affecting the evaluators of the ECS were:

a) probability function of each of the random variables

b) response and round-trip time is dependent upon detection, dispatching, first-aid times, victim location, ETU and ER location, node network

c) survival rate is dependent upon victim categories, treatment, time

6. Assumptions. The assumptions were:

a) All equipment, supplies and personnel perform identically (e.g., there is no performance difference between any two registered nurses).

b) ETU assumptions: If an ETU is cancelled, it will return to its station; an ETU will pick up victims according to a predefined triage policy in a multiple victim event.

c) If survival rate is used as an evaluator, prognosis curves can be constructed for specific victim categories.

IV.3 General Design of the Emergency Care Planning System Model

The Emergency Care Planning System model was designed as a planning tool to assist community planners in analyzing an emergency care system. This computer-based system will be described by considering first the primary design considerations and second by describing a general system flowchart of the ECPS model.

IV.3.1 Primary Design Considerations

There were several primary considerations in the design of the emergency care planning system. They were: flexibility, ease of use, and modification.

The flexibility of the system allowed it to be used to readily represent a number of different conditions or operating procedures in the emergency care system. A few of the more obvious changes in the conditions and operating procedures that the model could represent were:

1. varying the number, location, and equipment of the emergency transport units,
2. varying the emergency transport units between air and surface types,
3. varying the dispatching from regional to central,
4. varying the number and location of the emergency rooms,
5. varying triage policy,
6. varying transportation networks, and
7. varying assignment of medical personnel.

The ease of use of the system permits the user to interface at a high level with the system. This is especially true at the data input stage (see Appendix A). The form of the data is simple and does not require an understanding of the internal workings of the input module of the system. However, the system does not relieve the user of the responsibility for careful and accurate data collection. Also, the system does not prevent the user from using the system in an inappropriate manner, or from arriving at an incorrect conclusion. Proper use and accurate analysis of the results is basically a function of the ability of the users [23, 26, 28].

Modification of the system is relatively easy. The system has been designed and constructed in modular parts. Basic sections are well documented as to their interaction with other subsystems. Some modifications can be made by simply selecting different values for binary logic keys that are enetered as exogenous data. However, it was not, of course, possible to foresee all of the various changes in the model that would be desirable. Therefore, some modification may require actual alteration of the various submodules of the system. The modular design and documentation will facilitate such alteration.

IV.3.2 General Flowchart of the Emergency Care Planning System

As indicated in the flowchart in Figure IV.1, the ECPS is composed of numerous subsystems (each of which is also composed of smaller subsystems). These subsystems include: an input data generator and supervisor; a traffic network optimizer; and an ECS simulator. These and the other subsystems of the Emergency Care Planning System are described below.[1]

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[1]The details of these subsystems are presented in Appendix A and in ECPS Systems Manual, E. E. Payne, School of Industrial Engineering, University of Oklahoma, 1970.

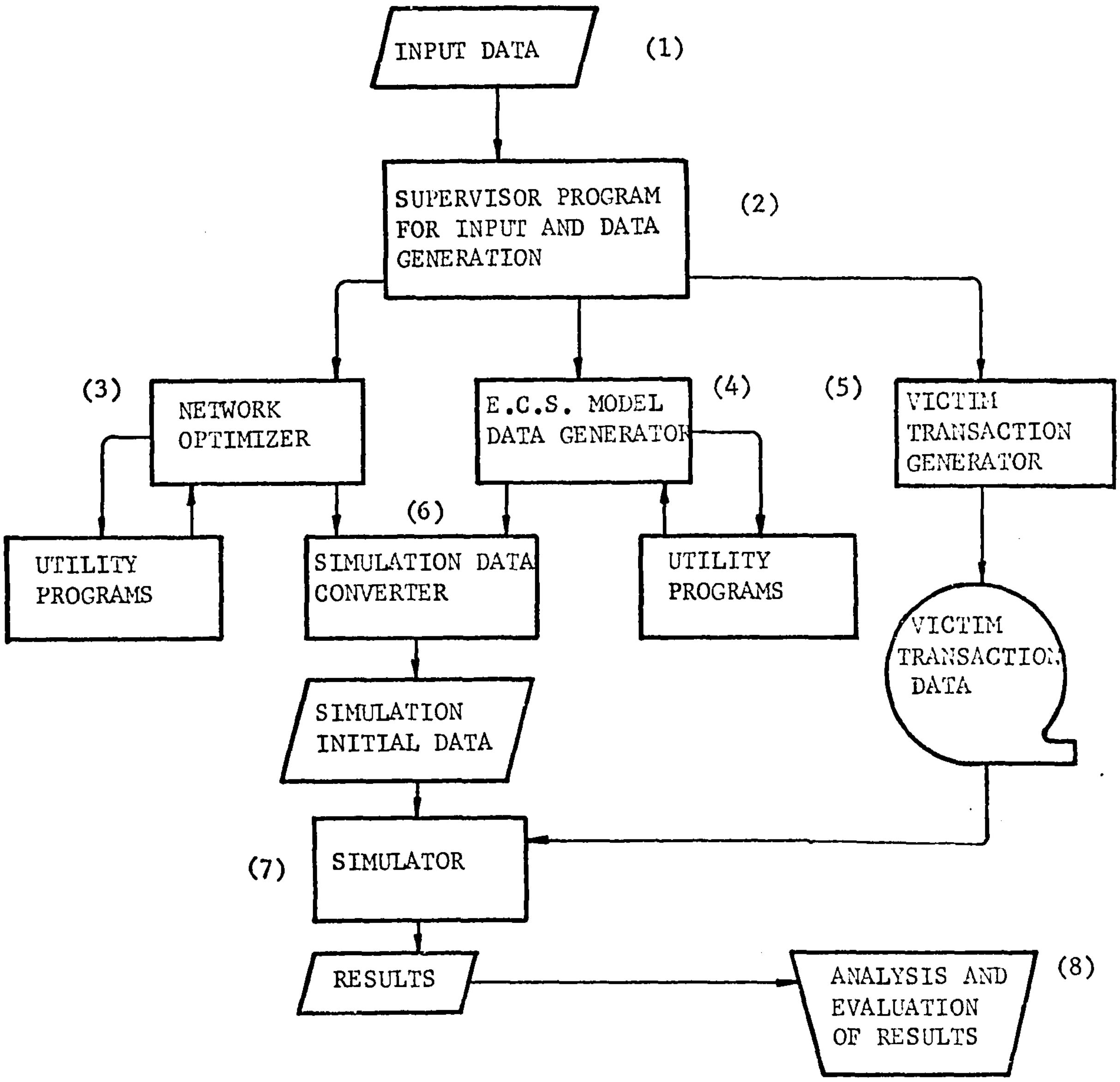


Figure IV.1 General Flowchart of ECPS.

1. Input. There are basically two types of data input to the model, variables and parameters. Variables, as discussed in Section IV.2, generally describe the variation of the system under consideration (e.g., the location of an emergency transport unit). A large amount of variable data are necessary to describe a community ECS. However, since the majority of this data is unchanged during the course of investigation, it would normally be necessary to collect this data only once for a complete study.

   Parameter data represents the control of the user over the system being investigated. These are data that are controllable by the user and can be altered from one investigation to the next (e.g., number of ambulances). Both variables and parameters are submitted via the input subsystems.

2. Supervisor. The supervisor program accepts the input data, converts it to the proper form, and then determines the proper subsystem to generate additional model data.

3. Network Optimizer. The network optimizer accepts network data from the supervisor program and then, with the assistance of various utility

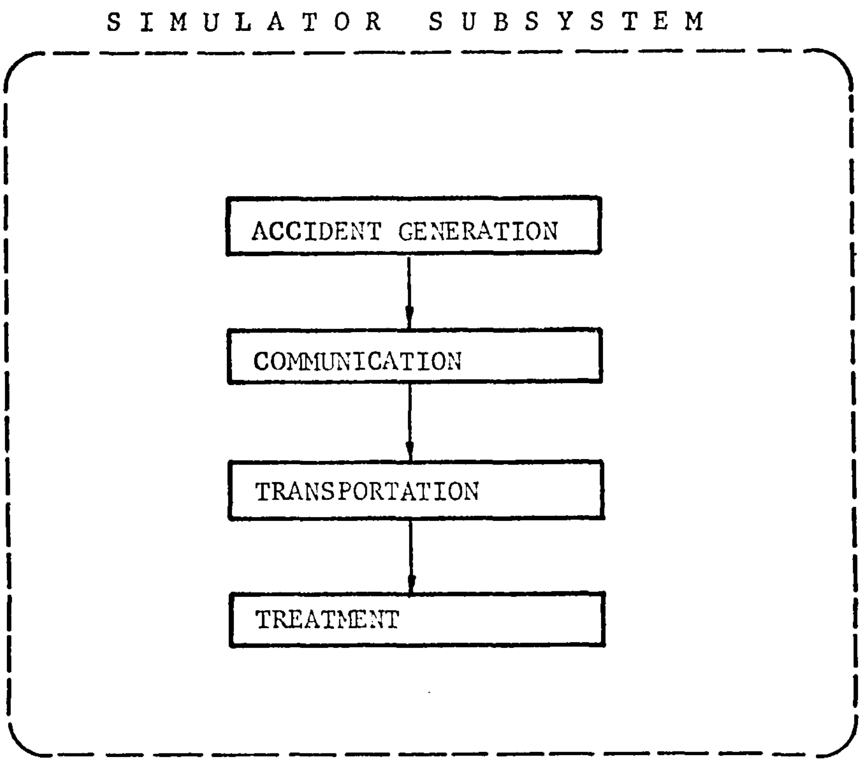


Figure IV.2 The Logical Subsystems of the Simulation Subsystem.

programs, determines the optimal path between all points in the transportation network (see Section IV.4.2).

4. <u>ECS Model Data Generator</u>. This subsystem accepts data from the supervisor that describes the ECS under consideration. It then converts and packs the data in the appropriate manner.

5. <u>Transaction Data Generator</u>. The Victim Transaction Data Generator accepts data from the supervisor program and generates a victim transaction data tape. This tape will be part of the variable input to the simulator program.

6. <u>Simulation Data Converter</u>. This subsystem accepts data from the network optimizer and ECS Model Data Generator and converts it into the proper form for the simulator.

7. <u>Simulator</u>. According to the terminology presented in Chapter III, the simulator subsystem could be described as an intermediate (level of detail), all-computer simulation. Also, it could be classified as a dynamic flow model with either deterministic or stochastic variables and parameters (at the user's option). Like the other major subsystem, the simulator subsystem is composed of several smaller modules. These smaller parts combine

to give the total system response which approximates the "real-world" process that is under investigation (see Figure IV.2).

a) Accident Generation -- This logical subsystem (of the Simulator subsystem) generates the accident entities. Each entity has several attributes, such as: time, place, number of victims, and type of injuries. These data attributes (and their associated attributes) might be either deterministic or probabilistic.

b) Communication -- The communication subsystem provides real-time control and coordination of the various resources of the system. The major function is, however, allocation of transportation facilities.

c) Transportation -- The transportation subsystem controls the movement of the individual transportation units once these units have been allocated.

d) Treatment -- This logical subsystem will determine triage policy, treatment, and derive survival rates for accident entities. Medical facilities will be allocated according to the plan specified by the user (parameter data). Survival rates, if they are used, will be a function of prognosis curves (injury type, treatment, and time).

8. Analysis and Evaluation. The results of the ECPS model are input to this manual process. The process involves appropriate consideration of the evaluators. Of course, this process may vary greatly from one run to another, depending upon the subject of investigation of the user [26].

IV.4 Design Details

The details of the Emergency Care Planning System model are discussed in the Appendix and elsewhere.[1] However, the logic of two of the more important unique developments of this model are discussed below.

IV.4.1 Survival Rate as an Evaluator

One of the evaluators that can be used with the ECPS model is survival rate. Unlike the other evaluators, discussed in Section II.5 and IV.2, an investigation revealed that survival rate has not been a well-defined evaluator for the emergency care system under normal

[1] *Ibid.*

operating conditions.[1] The primary difficulty that inhibits its use is that, to use survival rates one must have reasonable prognosis data.[2] Unfortunately, pathogenesis of deaths and injuries from traumatic injuries and emergency illnesses (e.g., highway accidents) is not generally known [46, pp. 3/2]. However, there has been research in recent years directed at the problem of estimating prognosis curves for a limited, specific list of traumatic injuries [46, 52, 74]. These data are usually assumed to be of the form shown in Figure IV.3 (see, also, Section II.4.1). The researchers have readily admitted that these curves are not exact, but only subjective estimates based upon educated medical opinion.

Although knowledge of the exact form of the prognosis curves was not necessary in the development of the planning model, a method for using these curves (when they are known) was necessary. In this research, a new method of representing and using prognosis data in a quantitative model was devised to permit: (1) the input of a variable number of injury/illness categories, (2) the

---

[1]The other evaluators are discussed in numerous sources, including: (1) response time [43, 41, 60]; (2) level of care [46, 52, 56, 66, 75, 86]; (3) cost [46, 56, 60, 79, 86].

[2]Prognosis data (a prognosis curve) describes the probability of mortality, for a specific injury/illness category, as a function of time and treatment (see Section II.4).

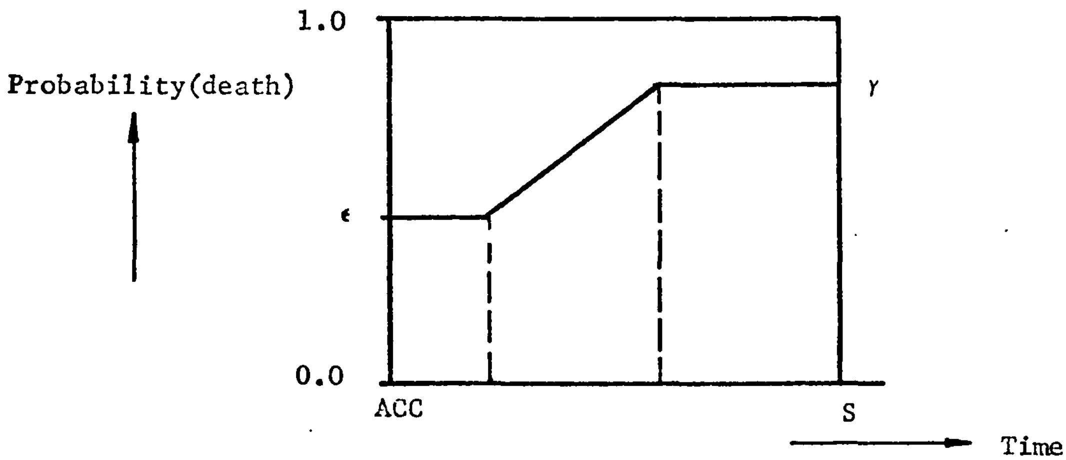


Figure IV.3 Prognosis Curve

TABLE IV.1--Terms Used in Prognosis Graphs

ACC	=	time of accident
S	=	the total time span over which the victim is observed
γ	=	probability of death at the end of the time span
ϵ	=	probability of immediate death

input of new or updated prognosis data, and (3) the calculation of survival rates where mortality is a function of injury-illness category, treatment, and time. A description of this method follows.

IV.4.1.1 Mortality as a Function of Time

In Figure IV.4 the probability of mortality is shown as a function of time. Normally, in the operating cycle (see Section II.3) of the emergency care system the mortality status of a victim has the greatest influence on the system responses at three basic points: the time first aid or paramedical care is available (FA); the time emergency medical care is available at the emergency room (EMC); and, the total time span over which the victim is being observed (S). The probability of mortality at each of these points is:

$\phi(t)$ = probability of mortality at t, given that the victim was alive at a prior check[1]

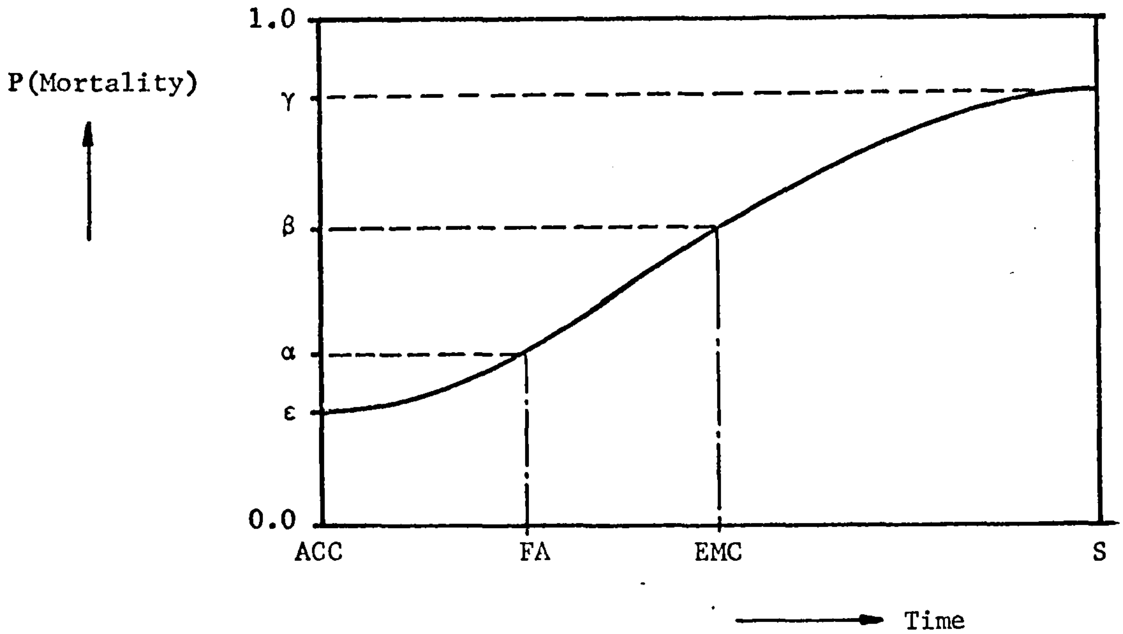
$$\phi(FA) = P(FA) = \alpha$$

$$\phi(EMC) = P(\text{mortality at EMC} \mid \text{alive at FA})$$
$$= P(A \mid B)$$
$$= \frac{P(A \cap B)}{P(B)} = \frac{\beta - \alpha}{1 - \alpha}$$

$$\phi(S) = P(\text{mortality at } S \mid \text{alive at EMC})$$
$$= P(C \mid D)$$
$$= \frac{P(C \cap D)}{P(D)} = \frac{\gamma - \beta}{1 - \beta}$$

---

[1]See Table IV.1 and Figure IV.4.



ACC	=	time of accident
FA	=	time first aid, paramedical care, or emergency medical care is available from the emergency transport unit (ETU)
EMC	=	time emergency medical treatment is available at the emergency room (ER)
S	=	the total time span over which the victim is being observed
ε	=	probability of immediate death
α	=	probability of mortality by time FA
β	=	probability of mortality by time EMC
γ	=	probability of mortality by end of time span, S

Figure IV.4 Probability of Mortality vs Time for a Specific Victim Category.

Example:

Let $\alpha = .4$

$\beta = .8$

$\gamma = .9$

M = 100 = victims in this category

Then,

E(mortality rate at FA) $= .4(100) = 40$

40 are dead at FA
60 are alive at FA

E(mortality rate at EMC) $= \left(\frac{.8 - .4}{.6}\right) 60 = 40$

40 of the 60 are dead at EMC
20 of the 60 are alive at EMC

E(mortality rate at S) $= \left(\frac{.9 - .8}{.2}\right) 20 = 10$

10 of the 20 are dead at S
10 of the 20 are alive at S

IV.4.1.2 Mortality as a Function of Time and Treatment

In Figure IV.4 the probability of mortality is shown as a function of time. In Figure IV.5 the effect on mortality of providing first aid at point FA is shown. It is assumed that this effort can be represented adequately by a multiplier factor, Π [52, 74, 80]. Also, as shown in Figure IV.6, the value of this multiplier factor is dependent upon whether first aid is administered before or after some time τ.[1]

---

[1]The time, τ, is a cut-off time. A specific treatment administered beyond this time is less effective. An investigation of research revealed no attempts to develop prognosis curves with this consideration.

If this same reasoning is also applied to emergency medical care that is available at time EMC, then the final probability of mortality at the end of the time horizon would be equal to the point γ in Figure IV.7. The new calculations for α, β, and γ are shown below.

1. Consider first aid and emergency medical care (at the emergency room) during two different times for each:

   a) $t_{FA} \leq \tau_1$ or $t_{FA} > \tau_1$

   b) $t_{EMC} \leq \tau_2$ or $t_{EMC} > \tau_2$

   The Π multiplier may be different for each of these times. In addition to τ, the multiplier, Π, is also dependent upon the care resources available (e.g., supplies, personnel). As shown in Table IV.2, three different levels of first aid and three different levels of emergency medical care may be considered for each victim category.

2. Let $\phi(t)$ = probability of victim dead at time t, given that the victim was alive at the prior check.

   Make calculations of $\phi(t)$ for t at FA, EMC, and S.

   $\phi(FA)$ = P(death immediately before arrival of ETU and availability of first aid, paramedical care,

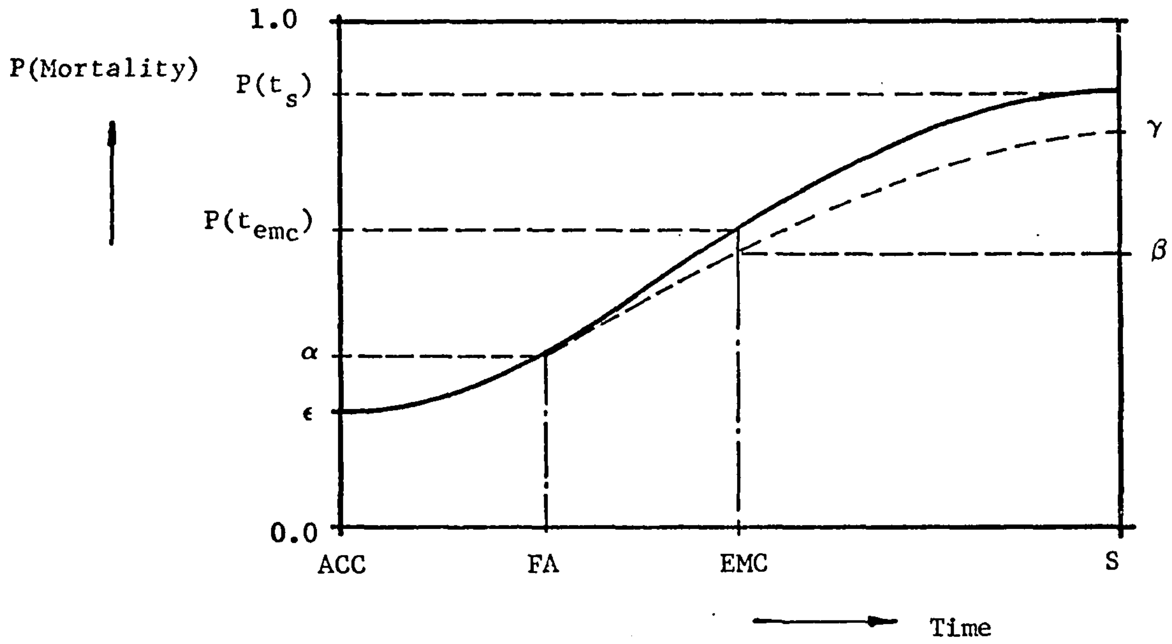


Figure IV.5 Probability of Mortality vs Time for a Specific Victim Category with π Multiplier for Treatment.

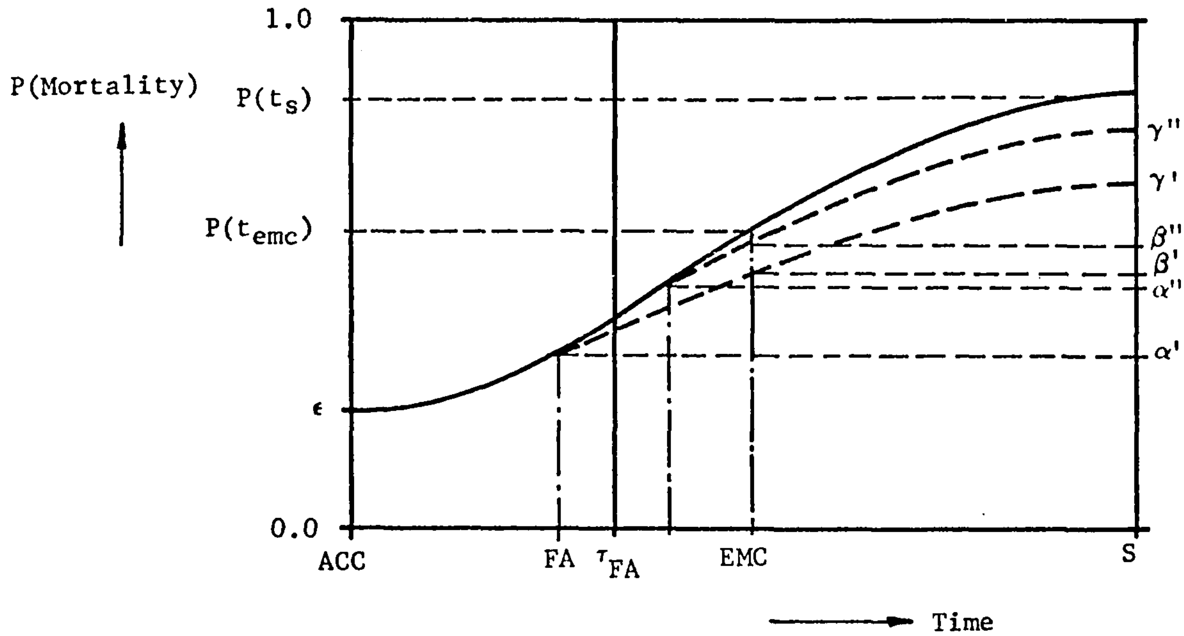


Figure IV.6 Probability of Mortality vs Time for a Specific Victim Category with π Multiplier for Treatment Before and After τ_{FA}.

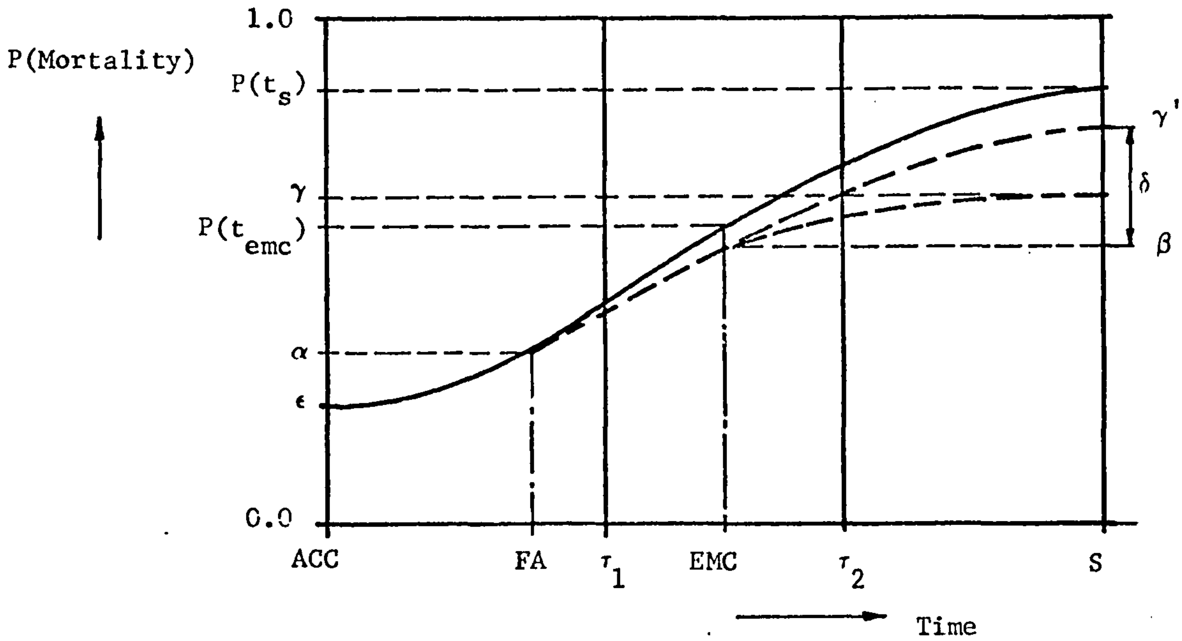


Figure IV.7 Probability of Mortality vs Time for a Specific Victim Category with π Multipliers for both First Aid and Emergency Medical Treatment Before and After τ_1 and τ_2.

or emergency medical care from ETU)

$$= P(t_{FA}) = a$$

$\phi(EMC)$ = P(death before emergency medical care is available at the emergency room | alive at FA)

$$= P(A \mid B)$$

$$= \frac{P(A \cap B)}{P(B)}$$

$$= \frac{\beta - a}{1 - a}$$

$$= \frac{a + (\Pi_{FA})(P(t_{EMC}) - a) - a}{1 - a}$$

where $\beta = a + (\Pi_{FA})(P(t_{EMC}) - a)$

Π_{FA} = f(time and level of first aid)

$\phi(S)$ = P(death before end of time horizon, S | victim alive at EMC)

$$= P(C \mid D)$$

$$= \frac{P(C \cap D)}{P(D)}$$

$$= \frac{\gamma - \beta}{1 - \beta}$$

where $\gamma = \beta + \Pi_{EMC}(\delta)$

$$\delta = \gamma' - \beta = a + \Pi_{FA}(P(t_S) - a) - \beta$$

$$= a + \Pi_{FA}(P(t_S) - a) - \beta$$

thus

$$\gamma = \beta + \Pi_{EMC}[\alpha + \Pi_{FA}(P(t_S) - \alpha) - \alpha - \Pi_{FA}(P(t_{EMC}) - \alpha)]$$

$$= \beta + \Pi_{EMC}[\Pi_{FA}(P(t_S) - P(t_{EMC}))]$$

$$= \alpha + \Pi_{FA}(P(t_{EMC}) - \alpha) + \Pi_{EMC}[\Pi_{FA}(P(t_S) - P(t_{EMC}))]$$

3. Consider a numeric example where the victim is classified in the victim category indicated by Table IV.2. Assume that first aid is available at FA = 18 minutes, and that emergency medical care is available at the emergency room at EMC = 27 minutes. The emergency transport unit and the emergency room are equipped as follows:

	Supplies[1] Available	Facilities[1] Available
ETU	Type 10,11,12, 13,17	Type 53
ER	Type 1,2,3,4,5, 6,8,10,11	Type 1,2,4,5,7, 8,14,23

[1]Supplies and facilities are separate entities. Supplies represent consumables, or entities that will not experience a simultaneous demand competition. Facilities represent entities that must be allocated to competing demands. The user must specify, as input to the model, the supplies and facilities of each victim category (see Table IV.2), emergency transport unit, and emergency room.

TABLE IV.2.--Levels of First Aid and Emergency Medical Care for a Specific Victim Category

	Required Supplies	Required Facilities	Time	Π_1	Π_2
EMC 1	Type 1,2,5	Type 1,2,7	20	.5	.6
EMC 2	Type 1,5	Type 1,7	10	.6	.8
EMC 3	Type 1	Type 1	10	.7	.8
FA 1	Type 10,11,14	Type 53	10	.8	.9
FA 2	Type 10,11	Type 53	10	.9	.95
FA 3			1	1.0	1.0

Time $\tau_{EMC} = 40$

Time $\tau_{FA} = 25$

Therefore, using the highest level treatment possible[1] (see Table IV.2), the Π multipliers would be $\Pi_{FA} = .9$, and $\Pi_{EMC} = .5$. Assume that the base prognosis curve for this victim category yields the following probabilities:

$$P(t_S) = .9$$

$$P(t_{EMC}) = .8$$

$$P(t_{FA}) = .5 = a$$

[1]First aid treatment, FA #2, was the highest level treatment (largest Π multipliers) that could be given because of the limited supplies on the ETU. Emergency medical care treatment, EMC #1, was the highest level treatment.

Then by direct calculation:

$$\alpha = P(t_{FA}) = .5$$

$$\beta = .5 + .9(.8 - .5)$$

$$= .5 + .27 = .77$$

$$\gamma' = .5 + .9(.9 - .5)$$

$$= .5 + .36 = .86$$

$$\gamma' - \beta = .86 - .77 = .09$$

$$\gamma = \beta + \Pi_{EMC}(\gamma' - \beta)$$

$$= .77 + .5(.09) = .815$$

By calculation in the above equations:

$$\beta = .5 + .9(.8 - .5) = .77$$

$$\gamma = .5 + .9(.8 - .5) + .5(.9(.9 - .8))$$

$$= .5 + .27 + .045$$

$$= .815$$

VI.4.2 Transportation Network

One of the more important parts of the emergency care system is the transportation network. A method was devised in this research which permits the user to input a transportation network (in the form of a node and arc network) that describes the street pattern of a metropolitan area under consideration. To enhance the reality of the network model, the user is permitted to specify two different types of networks. These may represent air and surface emergency transport units. Also, each network type may have several transportation patterns (an arbitrary limit of four) to represent different travel times during a twenty-four hour day. There are a maximum of sixty nodes. Figure IV.8 and Figure IV.9 show a simplified transportation network for a city. The arcs in this network represent the travel time from one point (node) to another point.

The network optimizer subsystem (see Figure IV.1) calculates the optimal travel time from one node to another node. That is, the network optimizer determines the minimum time to get from any one point in the transportation network to any other point.[1] This information is then made available to the simulation subprogram. The simulation subprogram uses this information to determine assignments of emergency transport units and emergency rooms. The basis for the calculations in the network optimizer is shown below.

---

[1]To travel to or from a point that is not exactly on a node of the network, a travel time (in addition to the node to node travel time), dependent upon the shortest distance, is calculated. This travel time is dependent upon the velocity factor for the particular area in question.

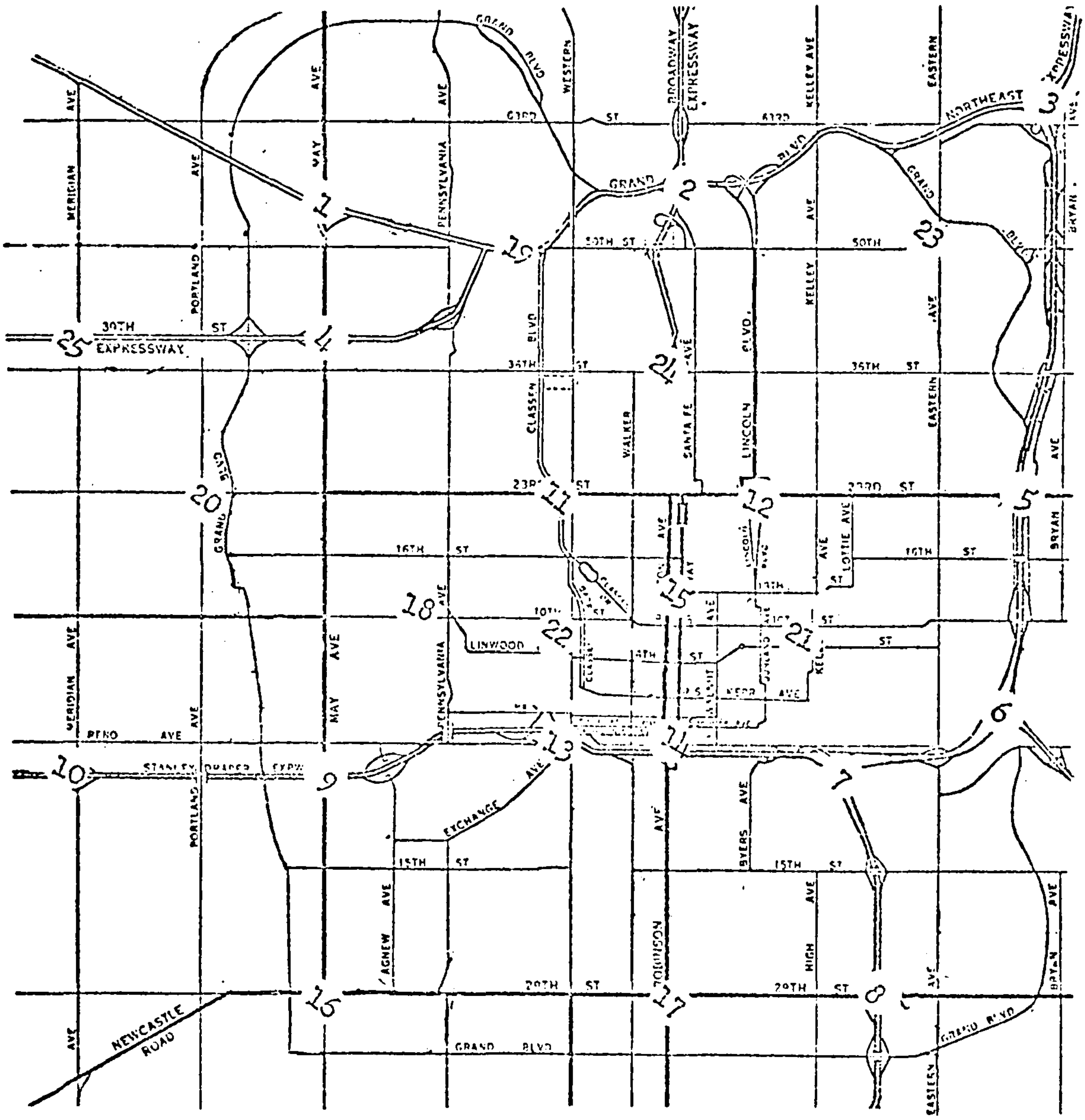


Figure IV.8 A Simplified Street Pattern (with nodes shown)

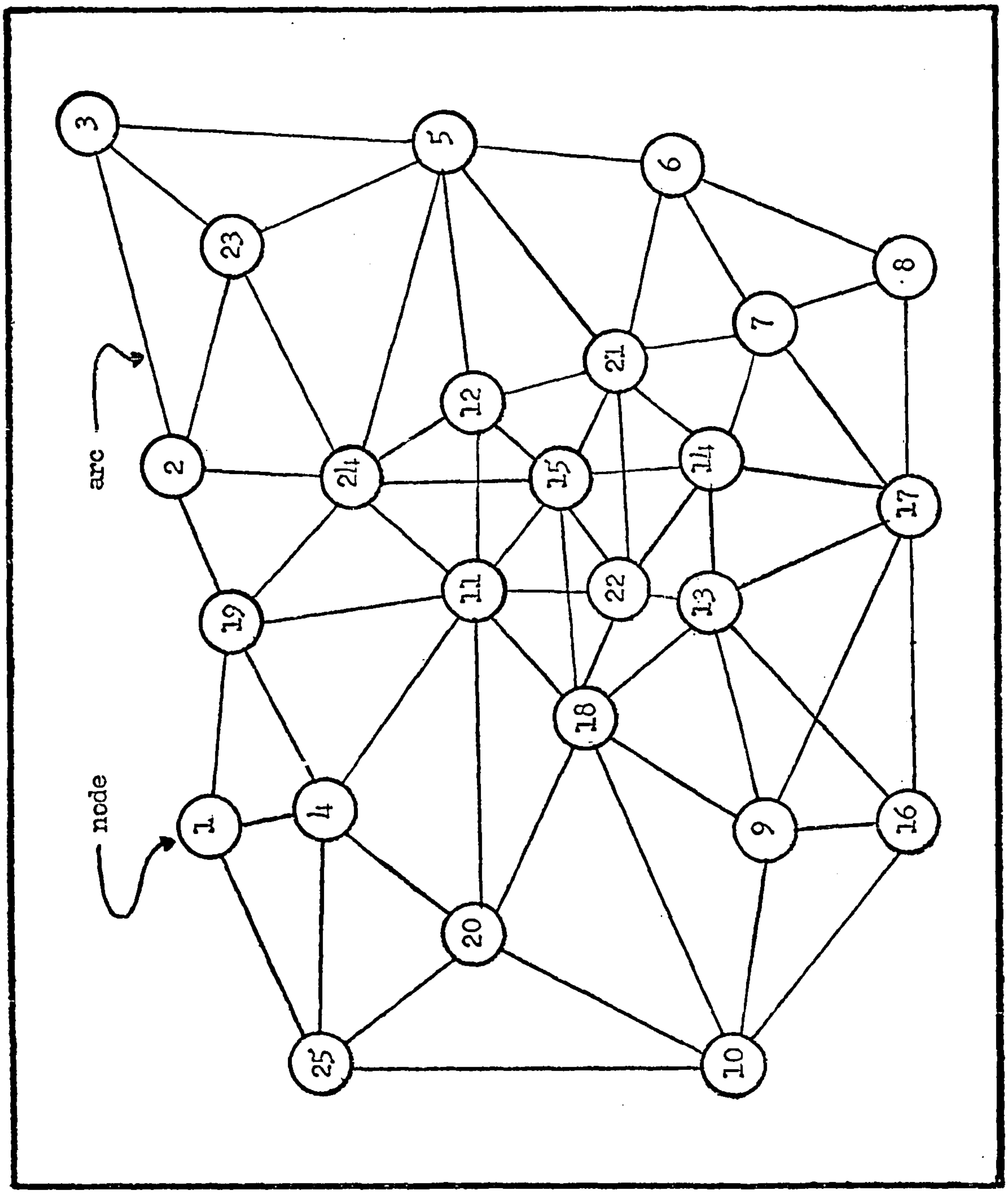


Figure IV.9 Representation of a Street Pattern by a Simplified Transportation Network

TABLE IV.3.--Terms used in Network Flow

Network	a set of nodes connected by arcs
N_i	node i
A_{ij}	the arc between node i and node j
d_{ij}	distance associated with arc A_{ij}
chain, C_{ik}	a sequence of nodes and arcs, starting at node i and ending at node k (does not contain any cycles)
cycle	a chain, C_{ik}, where $i = k$

The problem of calculating shortest chains in a directed, uncapacitated network[1] can be solved by several different algorithms.[2] However, because this is a multi-terminal problem (i.e., calculate shortest chains between all nodes in the network), an adaptation of an algorithm due to Hu was used.[3] This algorithm was found to be very efficient computationally.[4]

The method of the algorithm can be stated very briefly. It establishes pseudo-triangular inequality for a new set of d_{ij}.[5] This new set of d_{ij} represent the distances along a set of "basic" arcs. The distance, d_{ij},

---

[1]Terminology and notation is consistent with: T. C. Hu, Integer Programming and Network Flows. Reading, Mass.: Addison-Wesley Co., 1969, 105-76. (See also, Table IV.3.)

[2]*Ibid*.

[3]T. C. Hu, "Decomposition Alborithm for Shortest Paths in a Network," J. SIAM, 15, Jan. 1967, 207-18.

[4]Computation of 3600 shortest chains in a 60 node network took between one to two minutes CPU time on an IBM 360/50. Unfortunately, computation time is a cubic function of the number of nodes (instead of a linear function). However, this was not found to be a limitation in the node range required in this research ($N < 100$).

In the solution technique, as used in this research, the arcs were restricted to being non-negative. This prevented the occurrence of a negative cycle (and is entirely consistent with the transportation system logic).

[5]The distance along arc A_{ij} is equal to d_{ij} (if A_{ij} is non-existent, then d_{ij} is initially set equal to ∞). If for any two nodes, i and k, it is true that $d_{ik} \leq d_{ij} + d_{jk}$, then triangular inequality is said to exist (where j is any other node except i or k).

of each of these basic arcs is the shortest distance between the nodes i and j. For example, in Figure IV.10, the basic arc, A_{15} (which has an initial distance, d_{15}, equal to ∞) is constructed and found to have a distance, d_{15}, equal to 7.

The basic arcs are constructed by a "triple operation."

$$d_{ik} = \min (d_{ik}, d_{ij} + d_{jk}) \quad (\text{for all } j \neq k \neq i)$$

In other words, the algorithm operates by considering if passing through any intermediate node is shorter than going directly along the basic arc A_{ij}. If so, the distance d_{ik} is replaced by $d_{ij} + d_{jk}$. This comparison is continued in a logical fashion until it is no longer possible to reduce any d_{ik}. At this point the d_{ij} represent the shortest distance between all nodes i and j.[1]

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[1] A mathematical explanation and proof of this algorithm is given in T. C. Hu, Integer Programming and Network Flow. Reading, Mass.: Addison-Wesley, Co., 1969, 156-8.

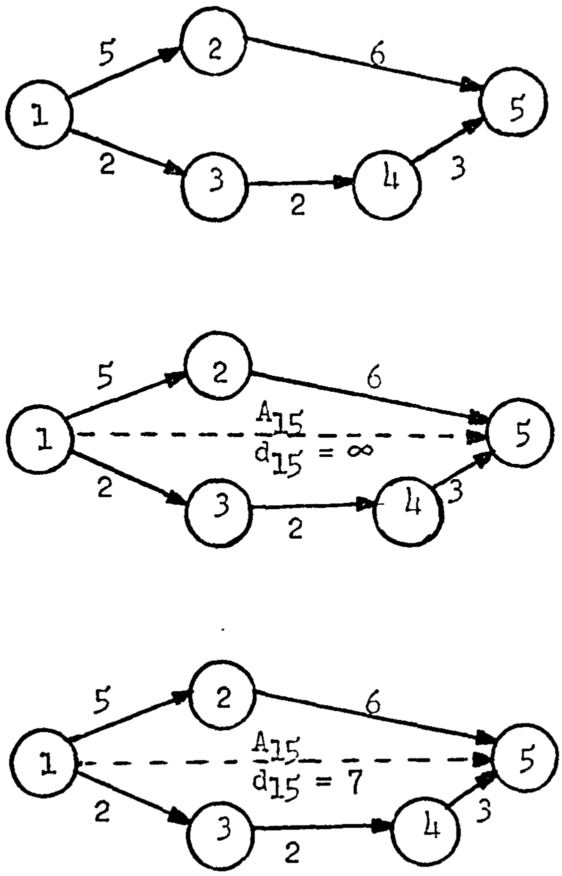

Figure IV.10 Addition of a Basic Arc to a Network.

IV.5 Use of the Emergency Care Planning System

Several authorities have proposed methods, utilizing computerized planning models, that community planners could use in the process of urban planning.[1] To illustrate how the central authority[2] of the community emergency care system could use a computerized planning model, such as the ECPS, a test case of a hypothetical planning situation is presented below. The data that describe this case are contained in Appendix E.

Situation: An independent study group has submitted a proposal to the central authority of the community ECS recommending: (1) centralization of the stationing of the emergency transport units to one station, and (2) reduction of the number of type 2 and type 3 emergency rooms[3] from six to two. According to the cost estimates of the proposal the community central authority (which controls and financially supports both ambulance service and the care of indigent patients in the emergency rooms) would realize annual savings of $18,000 in ambulance service and $45,000 in emergency room care.

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[1]For example, see [39, 52, 59, 60, 79, 85].

[2]See Section I.1 and I.3.

[3]See Section II.2.

Problem: Tentatively assume that the cost estimates of the study group are correct and use the Emergency Care Planning System model to investigate the effects of the proposed measures on response time, survival rate, and level of care.[1]

Solution: The analysts of the central authority must first determine the exact problem that is to be studied, and how evaluations are to be made. Then the analysts must determine how this problem can be adequately represented by the ECPS model. This step will determine what data must be collected. If the ECPS model has been used in other studies then data collection may not be a major concern (assuming the data are still current). However, if most of the data have not been collected, then data collection will be a large undertaking. The types of data that must be collected or specified include:

1. Victim data--These data describe the demands in the ECS. Each demand (call for help) is precisely defined. The

---

[1]It is assumed that: (1) a central authority exists, and (2) the central authority has the ability to quantitatively investigate and evaluate the community emergency care system. See Section I.1.

data that define each demand may include: number of victims in this call for help, case categories of victims, position of victims in the transportation network, medical preferences, and so forth.

2. Time scope--Total time over which to simulate the ECS (e.g., 2 days, 1 week).
3. Case descriptions--These are data that describe each of the victim categories. For each category the data may include: the basic prognosis curve, a precise description of the various first aid and emergency medical care treatments that may be given, the effects of the treatments upon the basic prognosis curve, and so forth.
4. Emergency room--Each emergency room is described by data that include: location in the transportation network, medical personnel types, facilities and supplies.
5. ETU--Each emergency transport unit is described with data that includes: present position in the transportation network, station position, communication facilities, capacity, facilities, supplies, and so forth.

6. Network data--Data describing the transportation network includes: the number of networks to consider, the nodes and arc times of each network, the time of the day each network is effective, and so forth.
7. Penalties --If penalty functions are used (optional) in the assignment of emergency transport units or emergency rooms, then these values must be specified.
8. Facilities and Supplies--Each facility and supply must be identified.
9. Binary Logic Keys--The user must specify a number of situations that he may or may not wish to consider. These include: do or do not give first aid to all victims at scene before transit of assigned patients, do or do not use victim emergency room preference, do or do not let dispatcher assign emergency rooms, and so forth.
10. Time functions--The times for performing numerous tasks must be specified either deterministically or as a probability function.
11. Miscellaneous--Other miscellaneous data must be specified (see Appendix E).

Although there is necessarily a large amount of data to be collected, the specifiction of these data is relatively easy for the user. Input to the various data generator subsystems of the ECPS model has been designed to be "user-oriented". An example of the format of some of these data is illustrated in Table IV.5.

The data used in this test case are contained in Appendix E. These are all the data that the user must specify. The input supervisor and data generation subsystems then generate various data that are required by the simulator subsystem. For example, the input supervisor inputs the network data, converts it to an internal form, and then calls the network optimization subsystem. There may be as many as eight networks input by the user. To specify each of these networks may require one to two hundred input data cards. However, the network optimizer (after finding the optimal traffic patterns) must then generate several tens of thousands of card images to describe each of the transportation networks.[1] These data are direct input for the simulator subsystem.

---

[1]Of course it is necessary for the ECPS model to utilize various system design techniques (e.g. word packing) to accommodate and handle the large amounts of data.

Results: The necessary data were collected and the computer runs were made to determine the effects of of the two conditions (from the proposal) upon the evaluators. A summary of the results is shown in Table IV.4. Under condition (1) a considerable negative effect was realized upon all three evaluators. Under condition (2) a negative effect, but smaller, was also realized.

Conclusions: On the basis of these results, without considering any alteration of the proposals[1], it can be concluded that proposal (2) is superior to (1) in both cost and service. However, both proposals have a negative effect on the evaluators of the system.[2]

---

[1]In an actual case study such alteration would be advisable to investigate. For example, it would be advisable to consider proposal (2) again, where fewer than four of the type 2 and type 3 emergency rooms were phased out. Also, proposal (2) might be considered where a portion of the cost savings (from closing four emergency rooms) were applied to upgrade the remaining two emergency rooms. It is possible that such a strategy could actually have a positive effect on the evaluators (at a lower cost).

[2]When considering a more complex situation, with more alternatives, the community planners may wish to use cost effectiveness evaluation. For an illustrated example of this technique see [79] .

Table IV.4 Evaluators of Test Case After Simulation of Case Load for One Week's Operation of ECS.

	Response Time (avg per call)	Survival Rate (% of total cases)	Level of Care[2]
Base Case[1]	17.5	98.7	66.3
Condition (1)	24.3	96.2	57.5
Condition (2)	21.9	97.4	63.4

[1]See Appendix E for description of data in base case.

[2]There are numerous ways to specify level of care. This central authority used: Percentage of victims, actually injured (not just a transport),that were given professional medical treatment in less than 20 minutes.

Table IV.5 Sample Listing of ECPS Input Data

```
                1     1     2     3     3     4     4     5
col 1     7     3     9     5     1     7     3     9     5
    VICTIM
          CALL
          TIME      84
          NODE      29
          NUMVIC     1     1
          ERPREF     1
          FAC       58    58
          FUNC      11    12    13
          CALL
          TIME     255
          .
          .
          .
    MODEL
          CASE       1
                EMC
                    40    70
                     7     8     1    20     2     1
                FA
                    30    60
                     2     5    10
                TIME      10    60
                FNPROG    11
                FNCALL    10
          CASE       2
          .
          .
          .
          ETU
                     2    13    44    22    13     0
          ETU
                     2    14    45     2    14     0
          .
          .
          .
    FACLTY      1    1      R NURSE
                2    1      R NURSE
                3    2      EMERG MED EQUIP 1
          .
          .
          .
```

CHAPTER V

CONCLUDING REMARKS

V.1 Summary

In this research the feasibility of developing a computerized planning model of the community emergency care system was investigated. To develop a computerized planning model it was first necessary to derive a definition of the ECS based upon its functional subsystems. This functional model was, in turn, used as a basis for developing a concise system description. An integral part of the system description was the objective and evaluators of the planning model. With the system description available, it was then possible to use various techniques to develop a computerized planning system.

The first phase of this research - defining the ECS - was initiated with a literature search to determine the accepted system definition of the emergency care system. However, the investigation revealed that in the United States there is not a standard, well-accepted definition of the community emergency care system and its functional components. In fact, this lack of a well-accepted system definition has been a contributing factor to some of the problems of the ECS. Among other things, the absence of a definition has made it difficult to measure performance, to establish state or national operating standards, to promote co-operation in the hospital community and to co-ordinate the various functions of the individual community emergency care systems.

Since a system definition had not been widely accepted, a definition based upon several proposed emergency care system "models", was formulated. The starting point in this formulation was a brief, subjective definition proposed by the American College of Surgeons. This organization defined the emergency care system as, " . . . that system that exists in a community for the purpose of saving lives and decreasing the probability of disabling injuries" [40]. The investigation also revealed that there had been two different types of models of the ECS developed: (1) a "medical" model, and (2) a more quantitative "functional" model. The definitions and descriptions in these models were extended to produce a systems model based upon the functional subsystems of the emergency care system. This systems model was then used to formulate a more concise "system description".

With a system description of the community emergency care system available as a basis, it was then possible to develop a computerized planning model. The technology used in this model included network flow and simulation techniques. A computerized model, the Emergency Care Planning System, was devised and tested with the data from a hypothetical community. There were several unique features developed in this planning model, however the most significant were the new survival rate evaluation system, and the method of handling transportation systems.

Survival rate is one of several evaluators that can be used with the Emergency Care Planning System that was developed in this study. However, unlike the other evaluators, survival rate has not been a well-defined evaluator for the community emergency care system. In this research a new method of representing prognosis data and calculating survival rate was devised to permit: (1) the input of a variable number of victim categories, (2) the input of new or updated prognosis data, and (3) the calculation of survival rates that are a function of victim category, time, and treatment (with treatment time limits).

The transportation system is one of the more important components of the emergency care system.

A method was devised in this research which permits the user to represent the transportation system with the movement of emergency transport units along various transportation networks (multiple networks to represent both surface and air vehicles and the time of day). The user describes the attributes of both the vehicles (e.g., capacity) and the networks (e.g., air or surface) according to the situation that he is investigating. A network optimization subsystem determines the shortest times between any two points in the transportation system along the appropriate network. The user also has the option of assigning emergency transport units according to other criteria in addition to availability and shortest transit time.

Test cases indicated reasonable computer solution times for data generation, network optimization, and ECS simulation. The sample cases reported all ran in less than twenty minutes on an IBM 360/50.

V.2 Recommended Future Research

During the course of this study several potential areas for future research were identified:

1. Demonstration Project.--Perhaps the most obvious area for an extension of the present research would be a demonstration project. This would be one or more actual case studies where the Emergency Care Planning System would be used to model and investigate actual emergency care

systems. Similar research has indicated that this demonstration project would require a large expenditure of funds and manpower [46, 52, 85, 86, 87]. However, funds and manpower may not be the most difficult problems.

The most difficult problems would perhaps be legal, sociological, and political. The purpose of the demonstration project would be to develop a coordinated, well planned, system for emergency care. However, to do this, it is not only necessary to develop the ability to quantitatively investigate and evaluate the ECS, but it is also necessary to establish a single, central authority responsible for the planning, coordination, and the control of the emergency care system in the community as a whole.
Therefore, a demonstration project would have to be a joint effort by the funding organization, the study group (system analysis and community planners), and the community political and medical structures.

2. Prognosis curves and victim categories.--Informal discussion with medical personnel revealed a consensus of opinion that survival rate is the best evaluator of the emergency care system. Other evaluators such as response time, round trip time, and levels of care are all actually assumed to be related directly to the survival rate of the

victims. The difficulty of using survival rate is, of course, that prognosis curves and victim categories have not been sufficiently developed.

Research directed at developing sufficient prognosis curves and victim categories would be of great use to the evaluation of emergency care systems. The results of this study have indicated that this information could be readily used. To develop this information would require a combined study with systems analysis and medical personnel. Also, it would probably require the development of an emergency victim information system to accumulate the necessary data. Such an information system does not normally exist in the emergency care system in most communities

3. Mathematical Programming Model of the Emergency Care System.--A review of published research indicated an absence of any attempt to construct a mathematical programming model of the community emergency care system. The only closely related research has been the construction of models in other areas (outside the area of medical systems) that might have some applicability to small parts of the total emergency care system.[1] There are probably a number of reasons why there has been an absence of the application of

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[1]For example, there have been numerous transportation models constructed that could possibly be applied to the dispatching of emergency vehicles.

mathematical programming. The most apparent reasons would seem to include:

a) Until recently the basic components and general relationships in the ECS had not been identified.

b) Many relationships in the ECS appear to be non-linear (e.g., prognosis curves).

c) There is no documentation system, now in use, that provides for the collection of all the necessary data to perform a case study and to develop the relationships in the mathematical programming model.

d) Specific objectives of the ECS (as proposed in this research) have not been quantified and accepted by medical and community authorities.[1]

e) Mathematical programming is probably not widely understood or used by personnel working in various capacities in the area medical care

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[1]Not only the emergency care system, but even a more readily definable part of the ECS, the emergency room, has not had specific quantitative objects developed. For example, the American College of Surgeons, committee on Trauma, which is a respected authority in the area of emergency service, defines the objective of the emergency department as: "the function of the emergency department is to give adequate appraisal and initial treatment or advice to any person who considers himself acutely ill or injured and presents himself at the emergency dept. door [40]." It may, in fact, be more desirable from the administrative point of view to have only a general objective, but the lack of a more specific objective makes model construction more difficult.

systems.

4. Emergency Transport Units.--Only limited research has been directed at investigating emergency transport units -- how they should be constructed, staffed, and equipped. This appears to be an area for numerous human factors study that could result in considerably improved vehicles.

5. Dispatching system.--One subsystem, of the Emergency Care Planning System, was aimed as optimizing the dispatching of the emergency transport units. This area of the study might be extended to the construction of a real-time, on-line computerized dispatching system. Such a system would, of course, require that the community have the necessary central control over emergency transport units.

V.3 Conclusions

This study has indicated that it is feasible to use quantitative techniques in the form of computerized models to assist community planners in their attempts to improve the community emergency care system. In addition, it has resulted in the development of a computerized planning system that could possibly be a valuable tool in planning emergency care systems.

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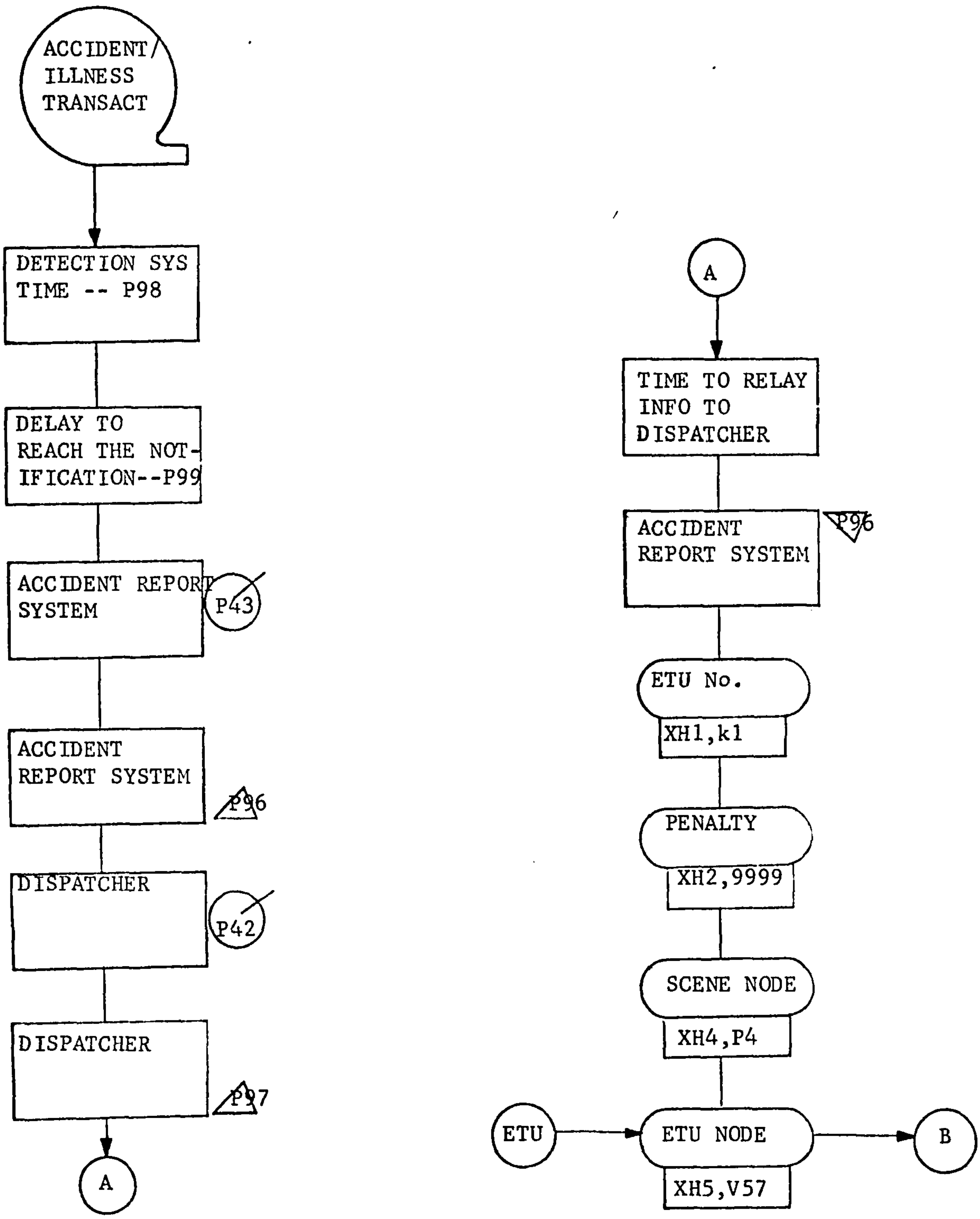
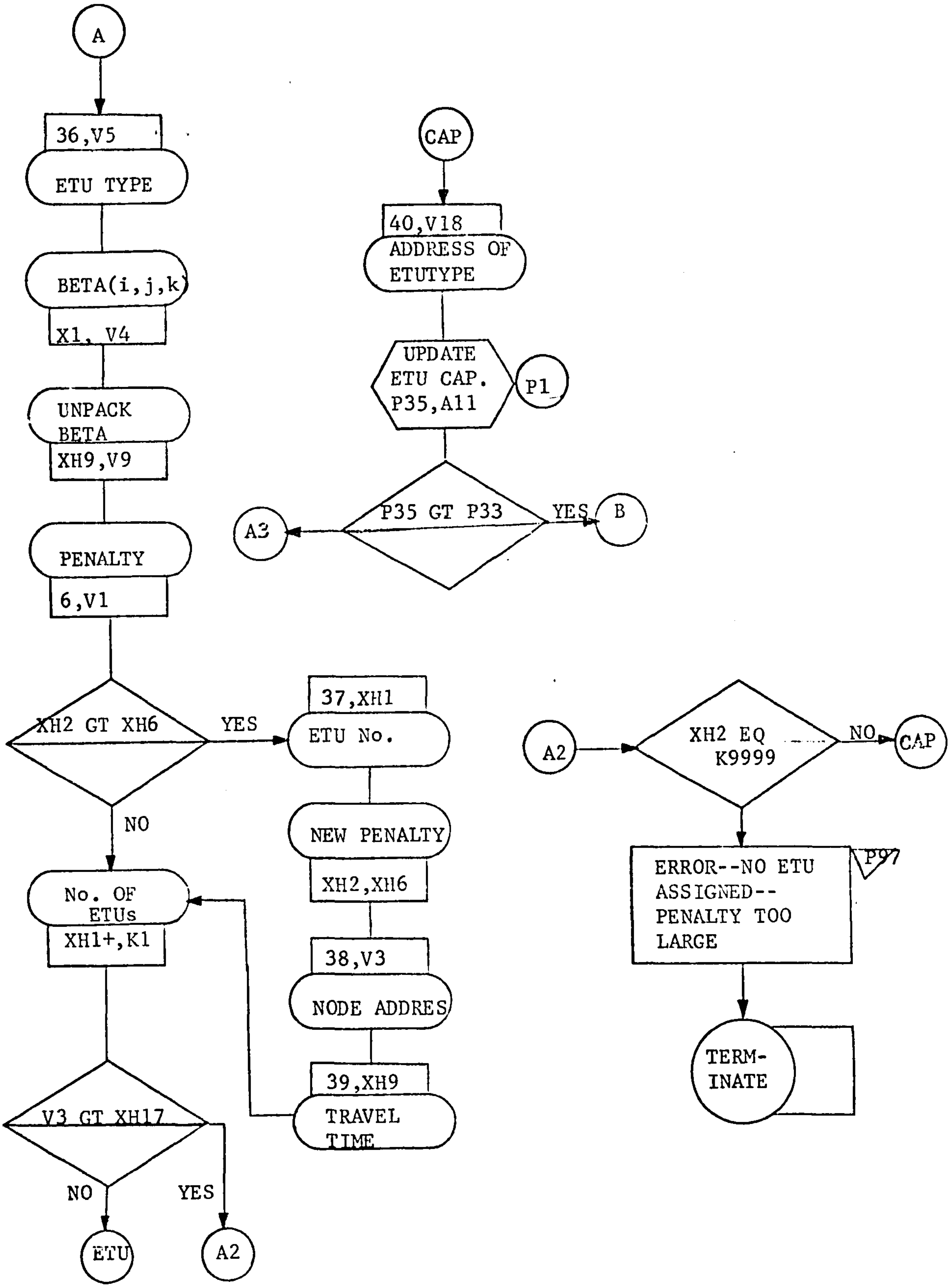
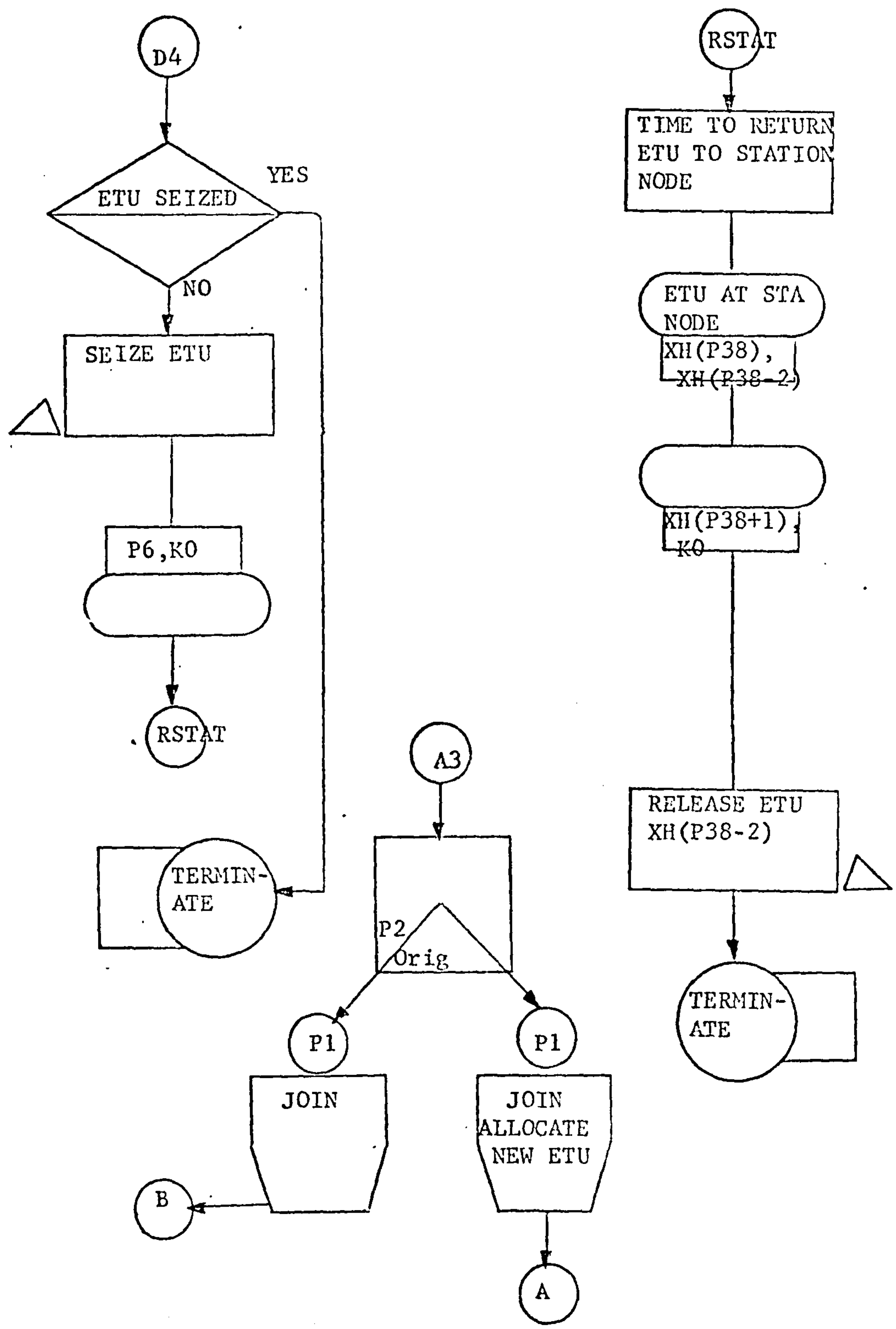
APPENDIX A

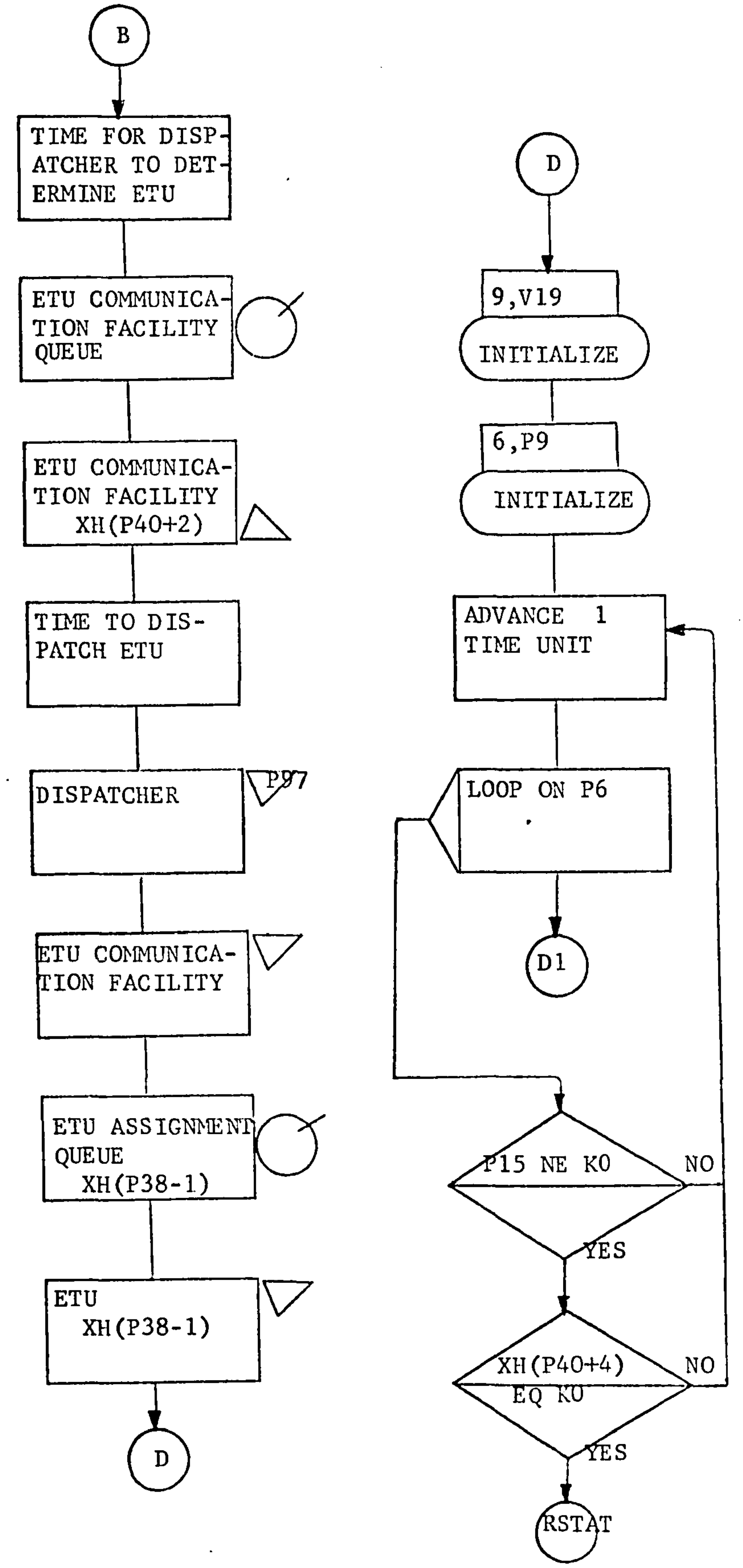
FLOWCHART OF SIMULATOR

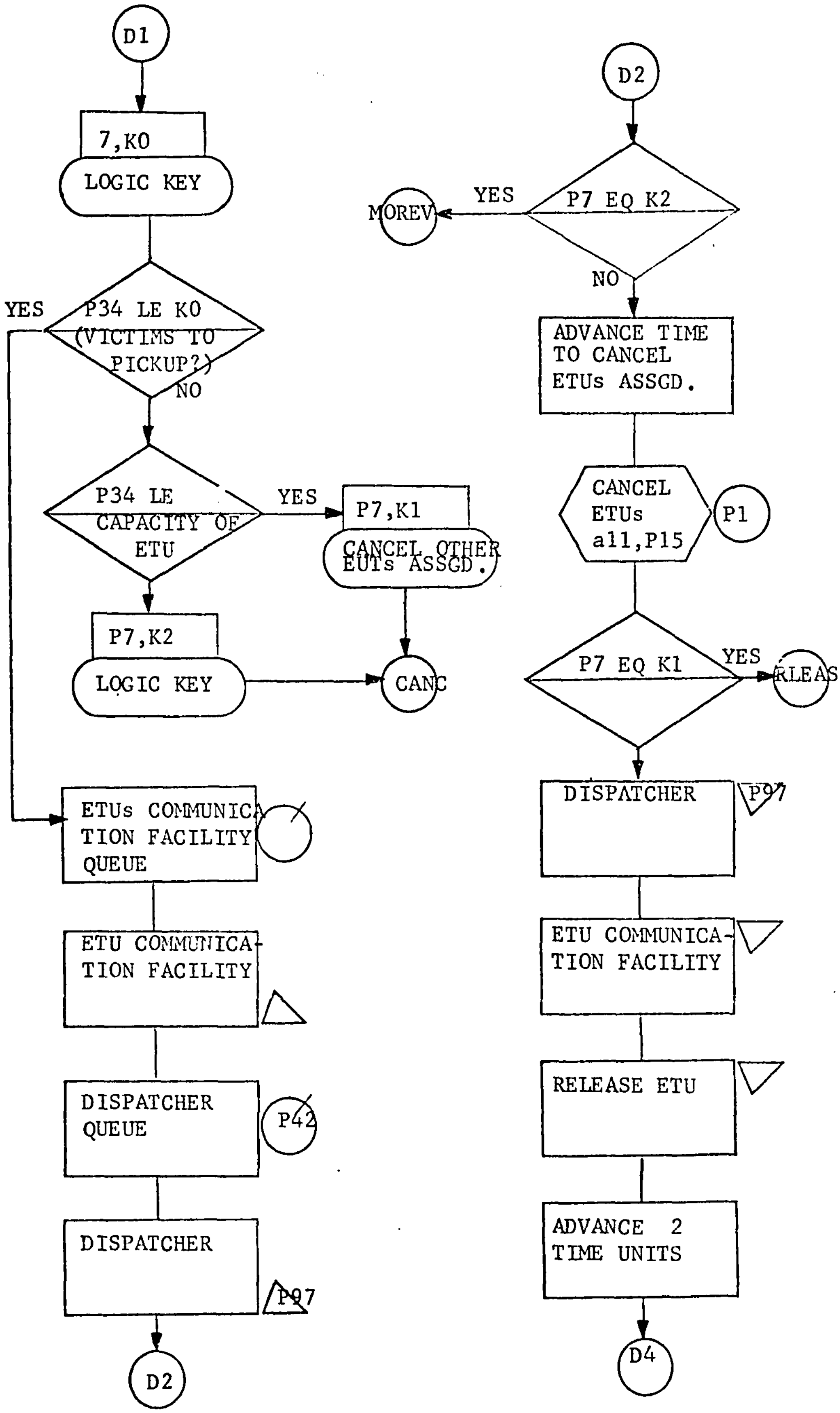
Below is a summary flowchart of the basic logic in the Simulator Subsystem of the ECPS model. For a detailed description of this Subsystem (transaction parameters, variables, tables, and so forth) see the ECPS Systems Manual.

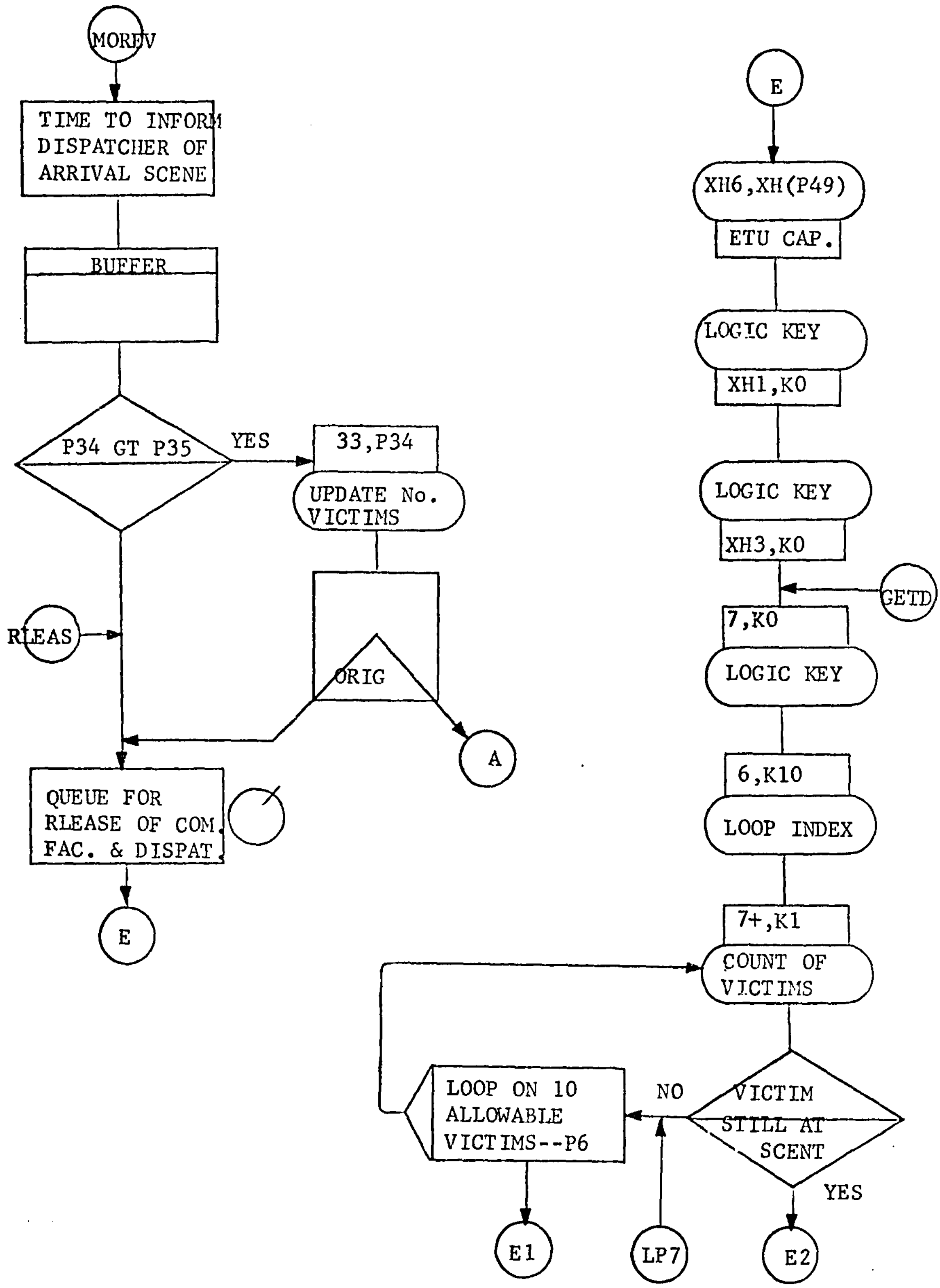

ACCIDENT/ ILLNESS TRANSACT
DETECTION SYS TIME -- P98
DELAY TO REACH THE NOT- IFICATION--P99
ACCIDENT REPORT SYSTEM
P43
ACCIDENT REPORT SYSTEM
P96
DISPATCHER
P42
DISPATCHER
P97
A
A
TIME TO RELAY INFO TO DISPATCHER
ACCIDENT REPORT SYSTEM
P96
ETU No.
XH1,k1
PENALTY
XH2,9999
SCENE NODE
XH4,P4
ETU
ETU NODE
XH5,V57
B

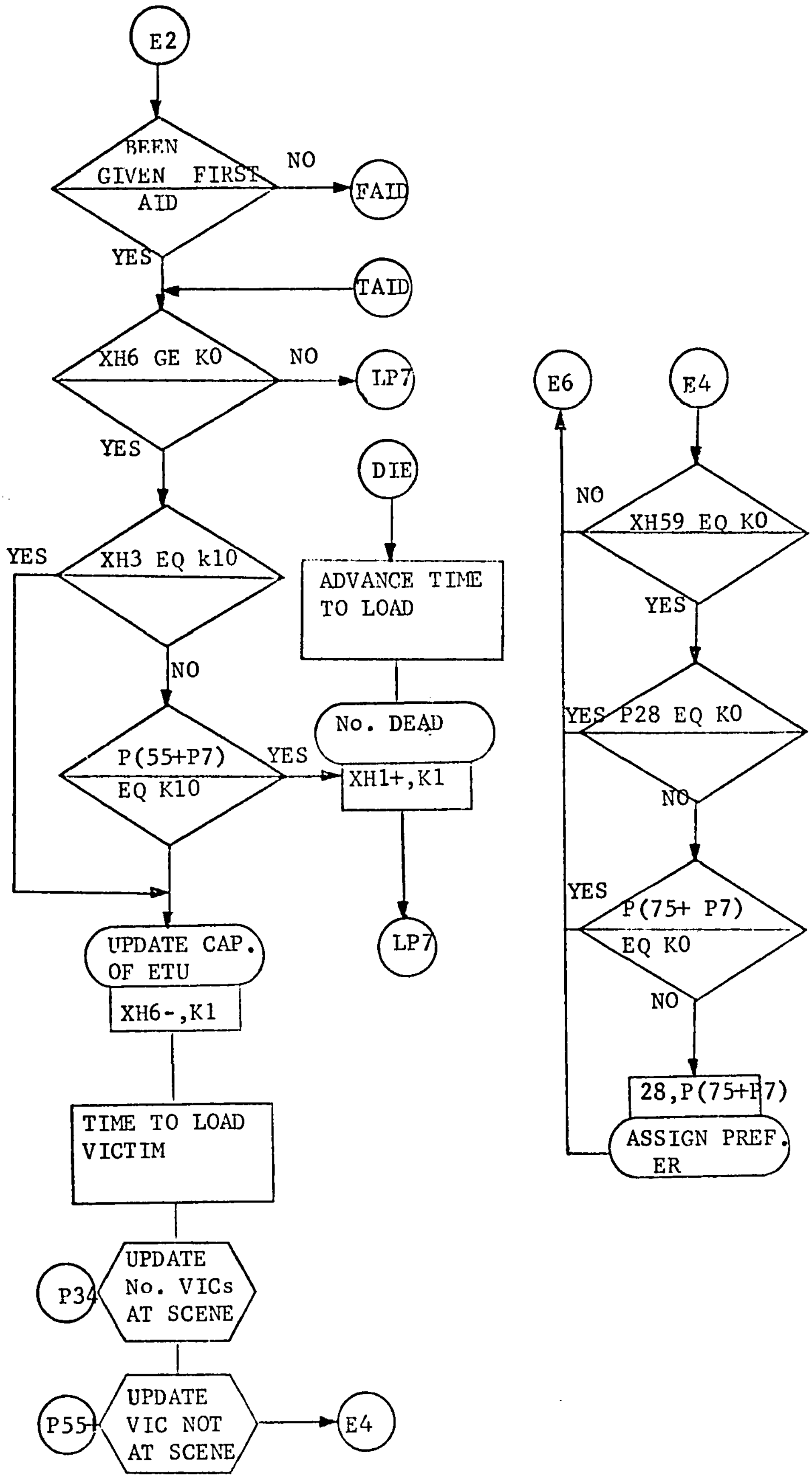

A
36,V5
ETU TYPE
BETA(i,j,k)
X1, V4
UNPACK BETA
XH9,V9
PENALTY
6,V1
XH2 GT XH6
YES
NO
37,XH1
ETU No.
NEW PENALTY
XH2,XH6
38,V3
NODE ADDRES
39,XH9
TRAVEL TIME
No. OF ETUs
XH1+,K1
V3 GT XH17
NO
YES
ETU
A2
CAP
40,V18
ADDRESS OF ETUTYPE
UPDATE ETU CAP. P35,A11
P1
P35 GT P33
YES
B
A3
A2
XH2 EQ K9999
NO
CAP
ERROR--NO ETU ASSIGNED--PENALTY TOO LARGE
P97
TERM-INATE

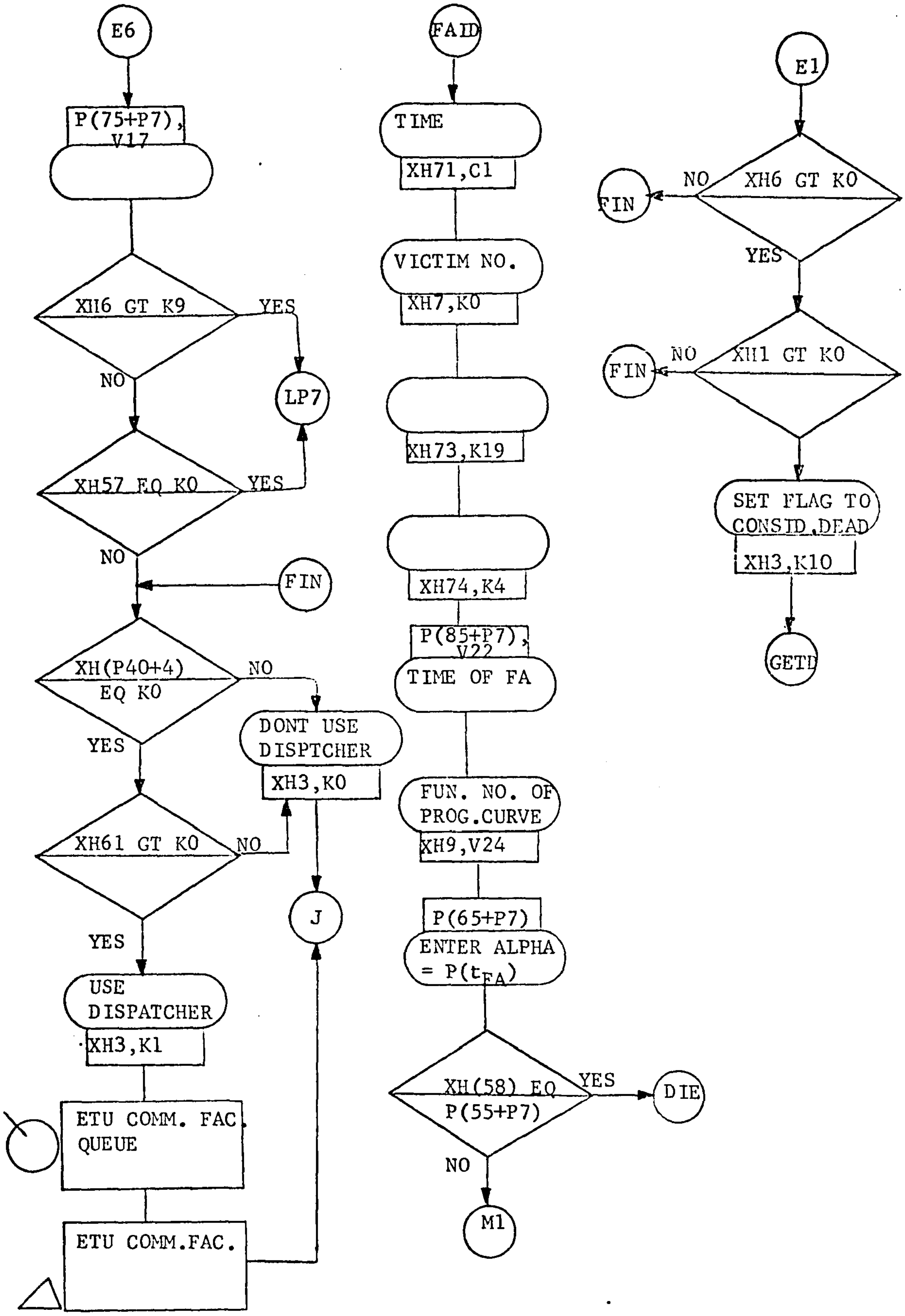

D4
ETU SEIZED
YES
NO
SEIZE ETU
P6,KO
RSTAT
TERMIN-
ATE
A3
P2
Orig
P1
JOIN
B
P1
JOIN
ALLOCATE
NEW ETU
A
RSTAT
TIME TO RETURN
ETU TO STATION
NODE
ETU AT STA
NODE
XH(P38),
XH(P38-2)
XH(P38+1),
KO
RELEASE ETU
XH(P38-2)
TERMIN-
ATE

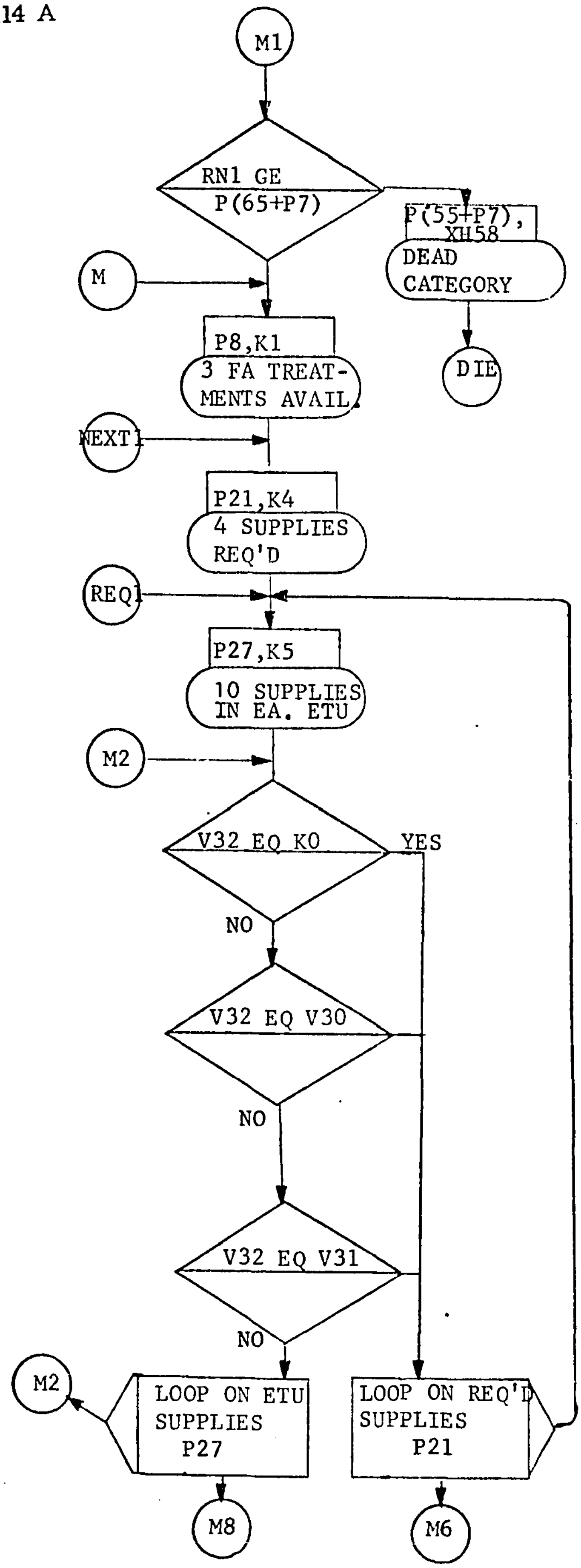

B
TIME FOR DISPATCHER TO DETERMINE ETU
ETU COMMUNICATION FACILITY QUEUE
ETU COMMUNICATION FACILITY XH(P40+2)
TIME TO DISPATCH ETU
DISPATCHER
P97
ETU COMMUNICATION FACILITY
ETU ASSIGNMENT QUEUE XH(P38-1)
ETU XH(P38-1)
D
D
9,V19
INITIALIZE
6,P9
INITIALIZE
ADVANCE 1 TIME UNIT
LOOP ON P6
D1
P15 NE K0
NO
YES
XH(P40+4) EQ K0
NO
YES
RSTAT

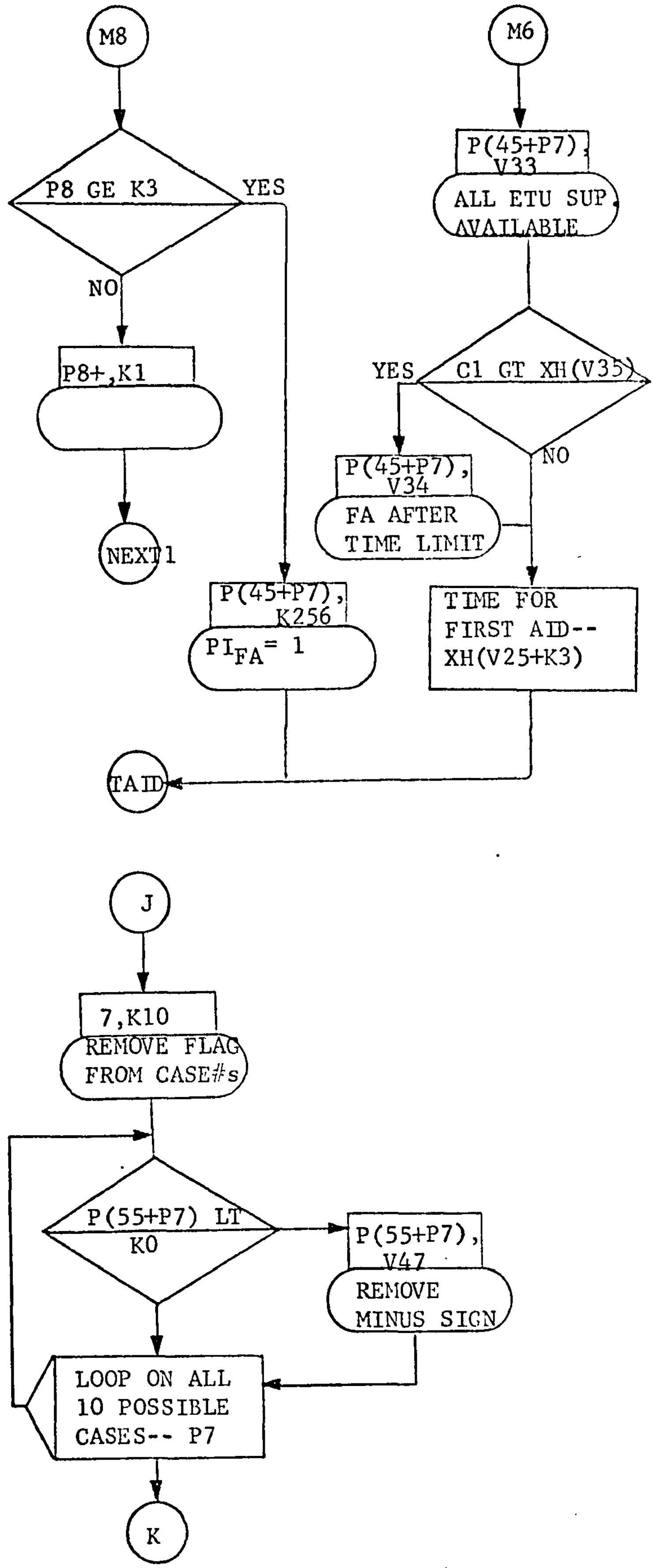

D1
7,K0
LOGIC KEY
YES
P34 LE K0
(VICTIMS TO
PICKUP?)
NO
P34 LE
CAPACITY OF
ETU
YES
P7,K1
CANCEL OTHER
EUTs ASSGD.
P7,K2
LOGIC KEY
CANC
ETUs COMMUNICA-
TION FACILITY
QUEUE
ETU COMMUNICA-
TION FACILITY
DISPATCHER
QUEUE
P42
DISPATCHER
P97
D2
D2
YES
P7 EQ K2
MOREV
NO
ADVANCE TIME
TO CANCEL
ETUs ASSGD.
CANCEL
ETUs
all,P15
P1
P7 EQ K1
YES
RLEAS
DISPATCHER
P97
ETU COMMUNICA-
TION FACILITY
RELEASE ETU
ADVANCE 2
TIME UNITS
D4

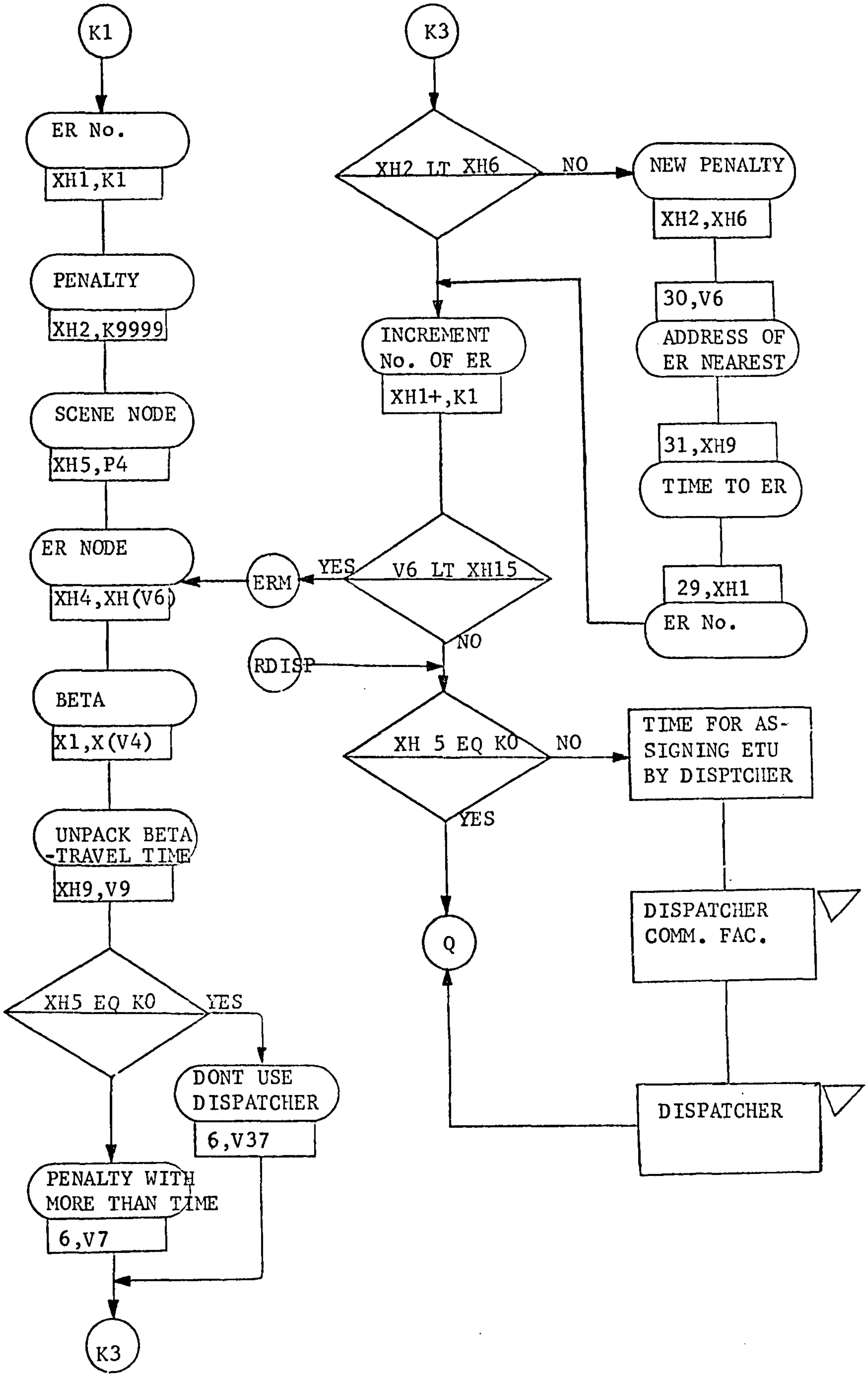

MOREV
TIME TO INFORM DISPATCHER OF ARRIVAL SCENE
BUFFER
P34 GT P35
YES
33,P34
UPDATE No. VICTIMS
ORIG
A
RLEAS
QUEUE FOR RLEASE OF COM. FAC. & DISPAT.
E
E
XH6,XH(P49)
ETU CAP.
LOGIC KEY
XH1,K0
LOGIC KEY
XH3,K0
GETD
7,K0
LOGIC KEY
6,K10
LOOP INDEX
7+,K1
COUNT OF VICTIMS
LOOP ON 10 ALLOWABLE VICTIMS--P6
NO
VICTIM STILL AT SCENT
YES
E1
LP7
E2

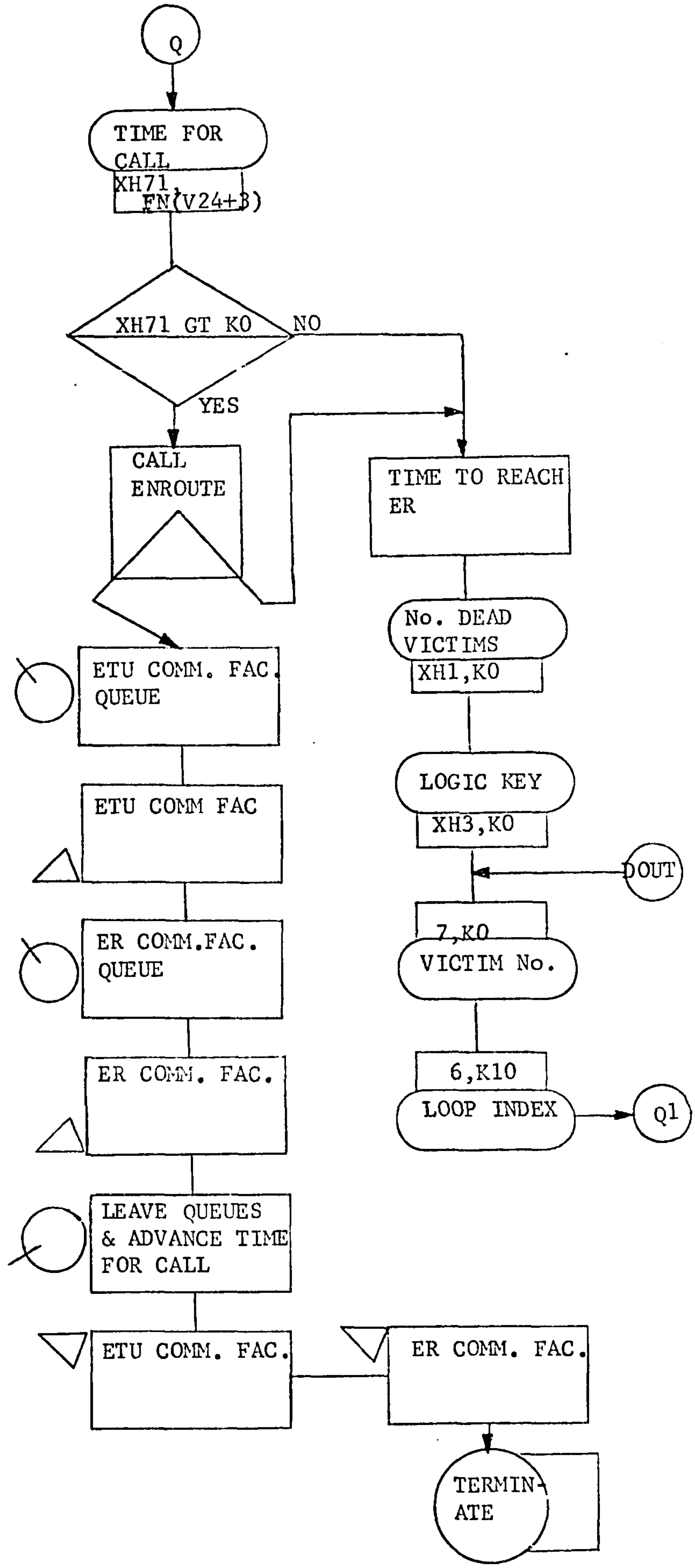

E2
BEEN GIVEN FIRST AID
NO
FAID
YES
TAID
XH6 GE K0
NO
LP7
YES
DIE
XH3 EQ k10
YES
NO
ADVANCE TIME TO LOAD
No. DEAD
XH1+,K1
P(55+P7) EQ K10
YES
LP7
UPDATE CAP. OF ETU
XH6-,K1
TIME TO LOAD VICTIM
P34
UPDATE No. VICs AT SCENE
P55+
UPDATE VIC NOT AT SCENE
E4
E6
E4
NO
XH59 EQ K0
YES
YES
P28 EQ K0
NO
YES
P(75+ P7) EQ K0
NO
28,P(75+P7)
ASSIGN PREF. ER

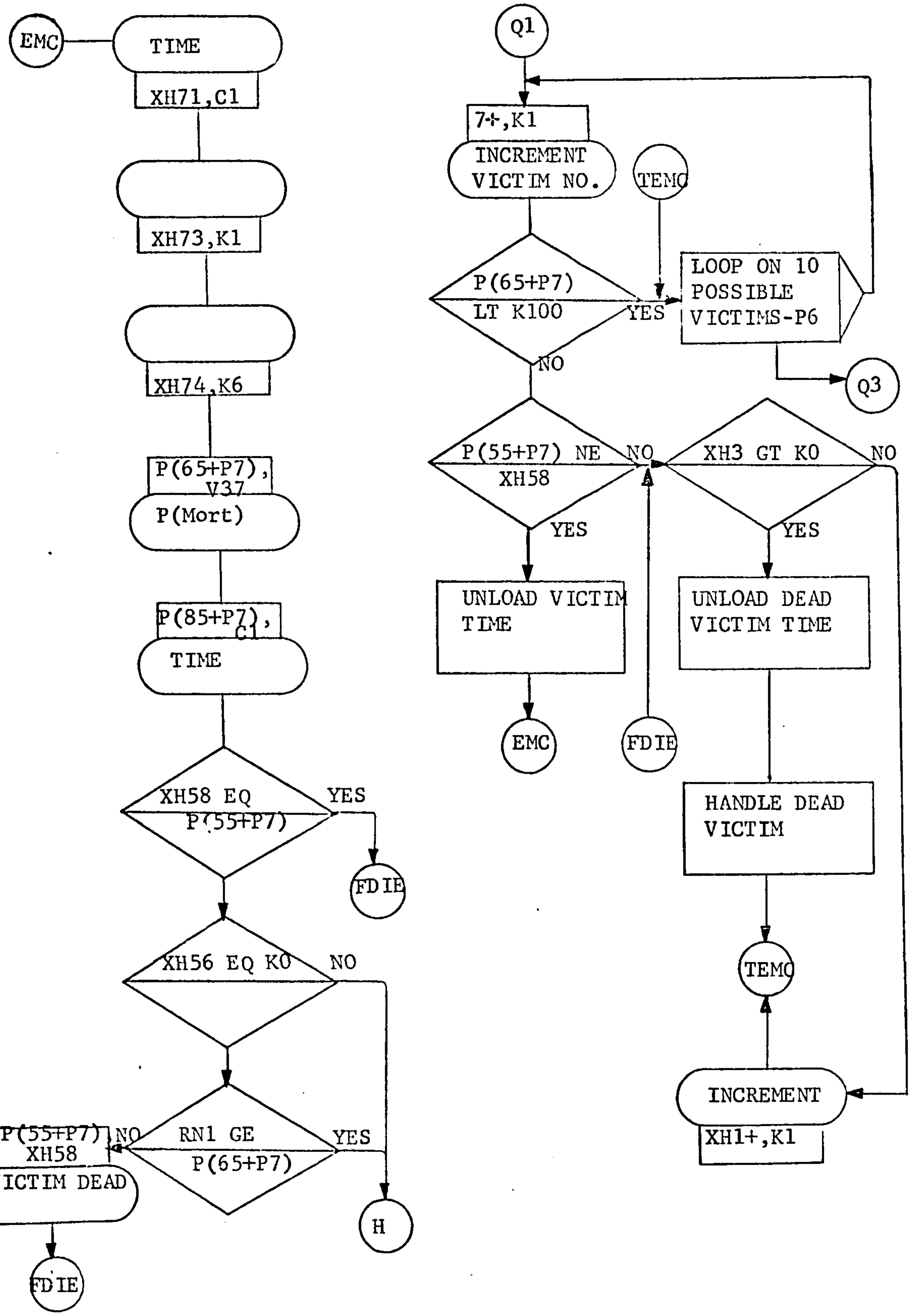

E6
P(75+P7), V17
XH6 GT K9
YES
NO
LP7
XH57 EQ K0
YES
NO
FIN
XH(P40+4) EQ K0
NO
YES
DONT USE DISPTCHER
XH3,K0
XH61 GT K0
NO
YES
J
USE DISPATCHER
XH3,K1
ETU COMM. FAC. QUEUE
ETU COMM.FAC.
FAID
TIME
XH71,C1
VICTIM NO.
XH7,K0
XH73,K19
XH74,K4
P(85+P7), V22
TIME OF FA
FUN. NO. OF PROG.CURVE
XH9,V24
P(65+P7)
ENTER ALPHA = P(tFA)
XH(58) EQ P(55+P7)
YES
DIE
NO
M1
E1
XH6 GT K0
NO
FIN
YES
XH1 GT K0
NO
FIN
SET FLAG TO CONSID.DEAD
XH3,K10
GETD

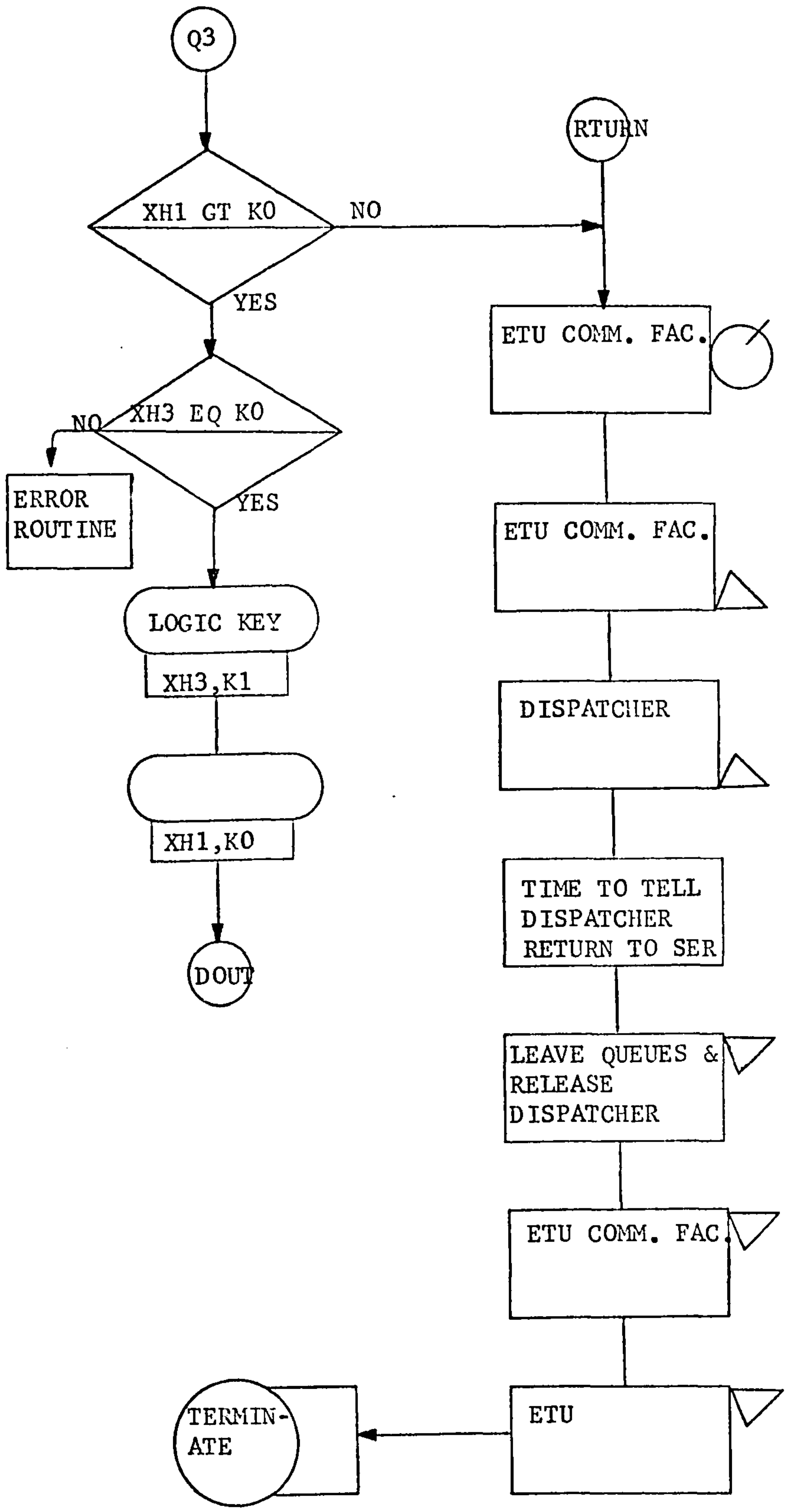

M1
RN1 GE
P(65+P7)
P(55+P7),
XH58
DEAD
CATEGORY
DIE
M
P8,K1
3 FA TREAT-
MENTS AVAIL
NEXT1
P21,K4
4 SUPPLIES
REQ'D
REQ1
P27,K5
10 SUPPLIES
IN EA. ETU
M2
V32 EQ K0
YES
NO
V32 EQ V30
NO
V32 EQ V31
NO
M2
LOOP ON ETU
SUPPLIES
P27
LOOP ON REQ'D
SUPPLIES
P21
M8
M6

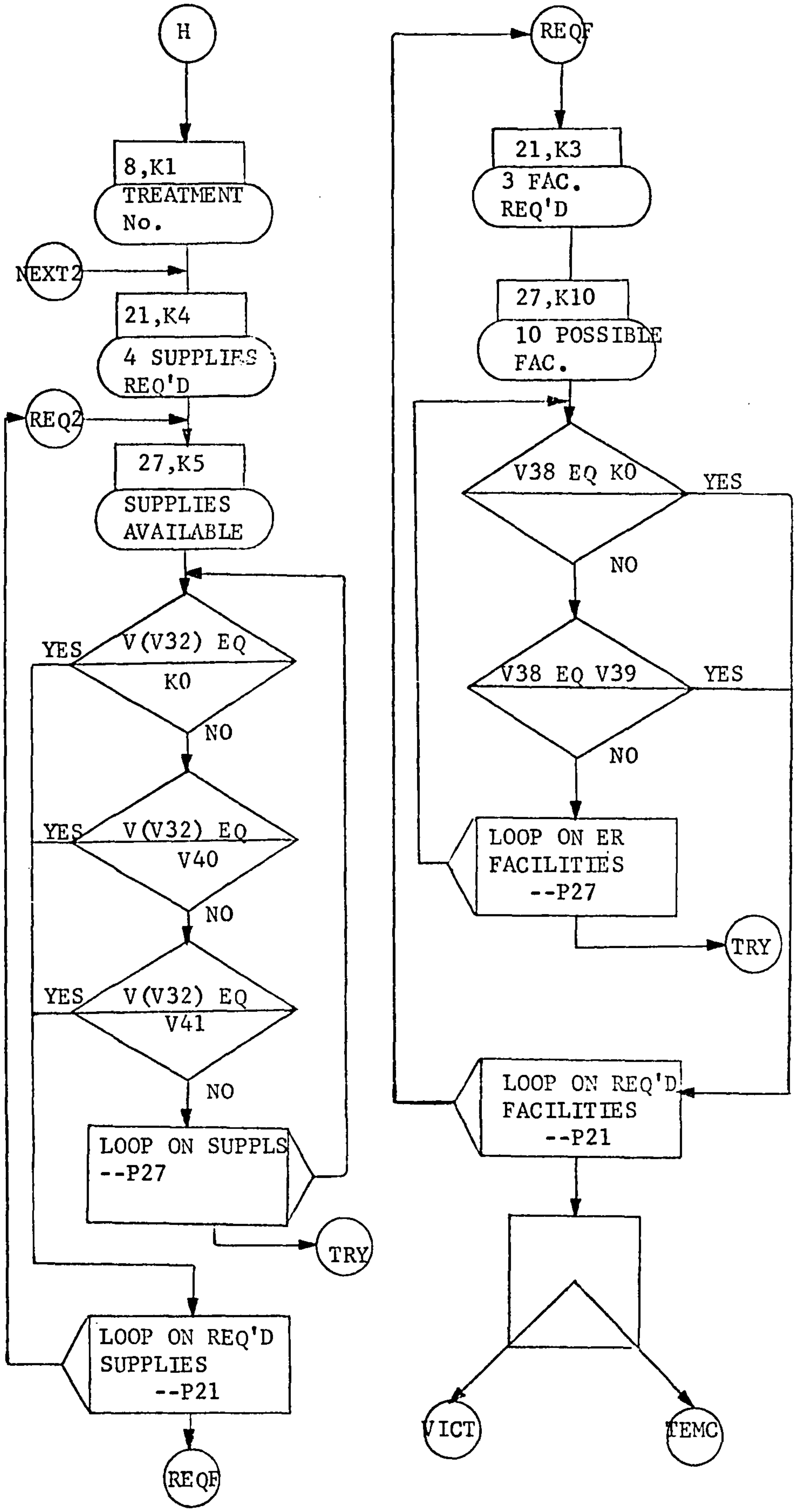

M8
P8 GE K3
YES
NO
P8+,K1
NEXT1
P(45+P7), K256
PI_{FA} = 1
TAID
M6
P(45+P7), V33
ALL ETU SUP. AVAILABLE
YES
C1 GT XH(V35)
NO
P(45+P7), V34
FA AFTER TIME LIMIT
TIME FOR FIRST AID-- XH(V25+K3)
J
7,K10
REMOVE FLAG FROM CASE#s
P(55+P7) LT K0
P(55+P7), V47
REMOVE MINUS SIGN
LOOP ON ALL 10 POSSIBLE CASES-- P7
K

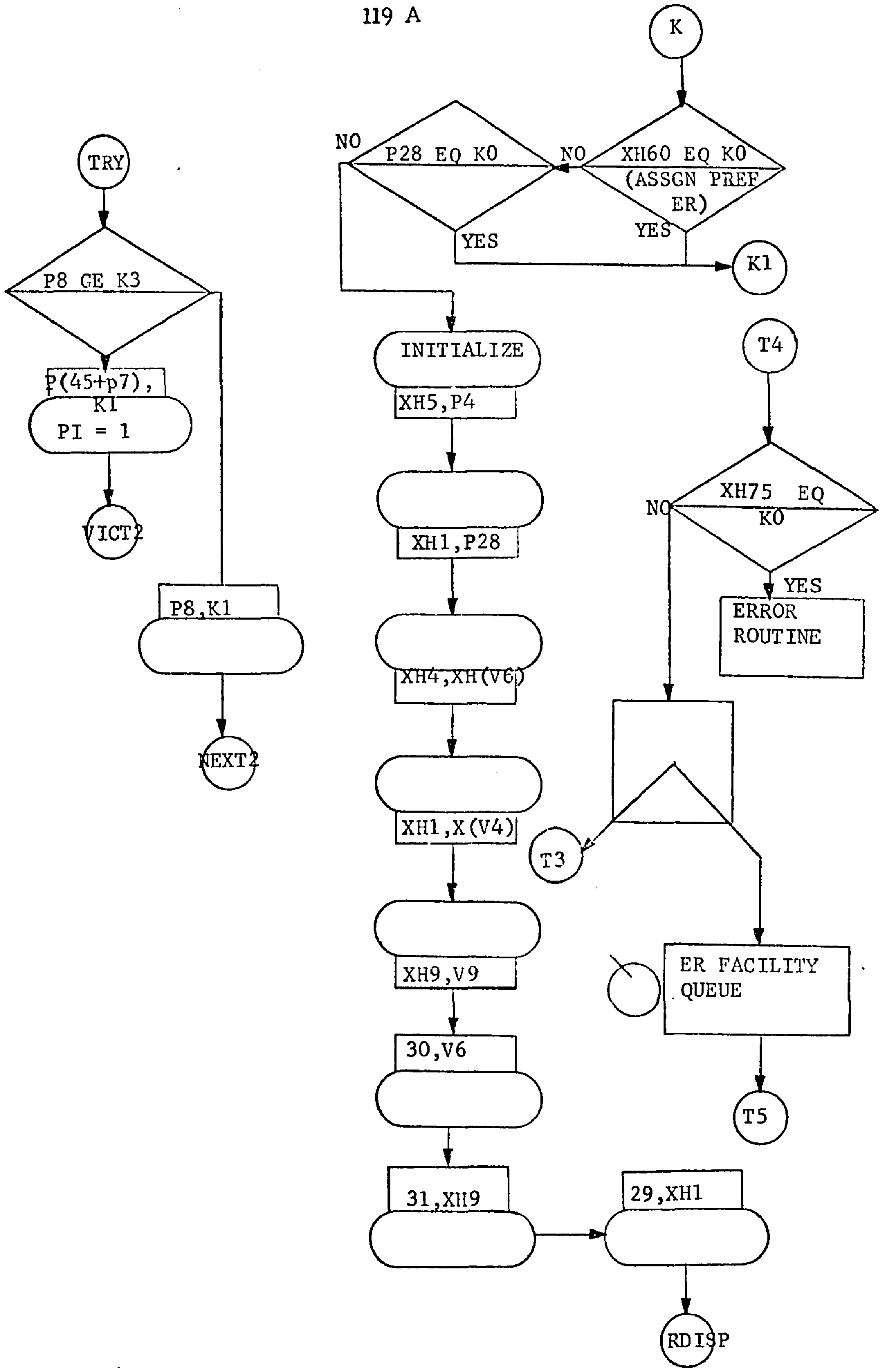

K1
ER No.
XH1,K1
PENALTY
XH2,K9999
SCENE NODE
XH5,P4
ER NODE
XH4,XH(V6)
BETA
X1,X(V4)
UNPACK BETA -TRAVEL TIME
XH9,V9
XH5 EQ KO
YES
DONT USE DISPATCHER
6,V37
PENALTY WITH MORE THAN TIME
6,V7
K3
K3
XH2 LT XH6
NO
NEW PENALTY
XH2,XH6
30,V6
ADDRESS OF ER NEAREST
31,XH9
TIME TO ER
29,XH1
ER No.
INCREMENT No. OF ER
XH1+,K1
V6 LT XH15
YES
ERM
NO
RDISP
XH 5 EQ KO
NO
TIME FOR AS- SIGNING ETU BY DISPTCHER
YES
Q
DISPATCHER COMM. FAC.
DISPATCHER

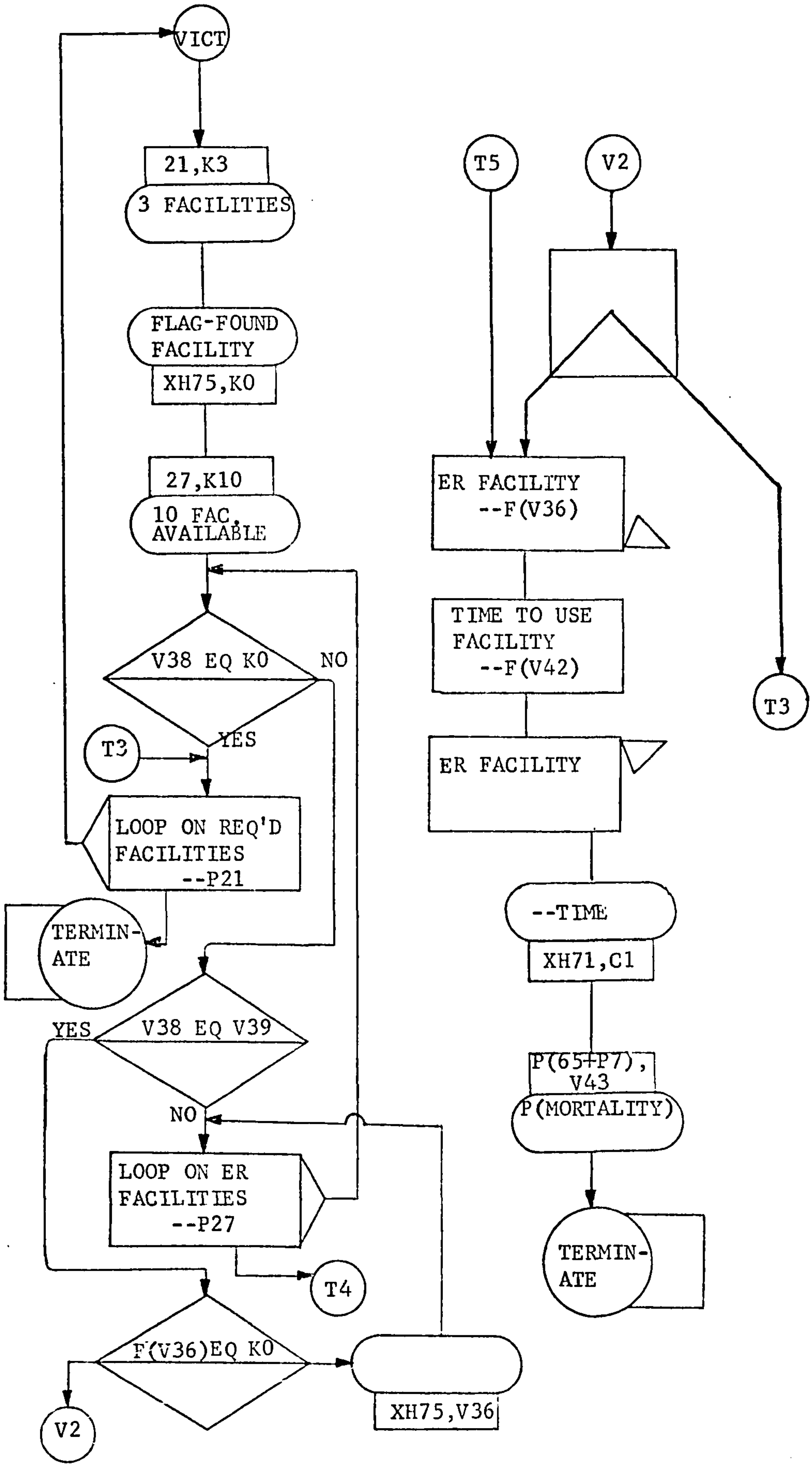

Q
TIME FOR CALL
XH71, FN(V24+3)
XH71 GT K0
NO
YES
CALL ENROUTE
TIME TO REACH ER
No. DEAD VICTIMS
XH1,K0
ETU COMM. FAC. QUEUE
LOGIC KEY
XH3,K0
ETU COMM FAC
OUT
ER COMM.FAC. QUEUE
7,K0
VICTIM No.
ER COMM. FAC.
6,K10
LOOP INDEX
Q1
LEAVE QUEUES & ADVANCE TIME FOR CALL
ETU COMM. FAC.
ER COMM. FAC.
TERMIN-ATE


EMC
TIME
XH71,C1
XH73,K1
XH74,K6
P(65+P7), V37
P(Mort)
P(85+P7), C1
TIME
XH58 EQ P(55+P7)
YES
FDIE
XH56 EQ K0
NO
RN1 GE P(65+P7)
YES
NO
H
P(55+P7) XH58
VICTIM DEAD
FDIE
Q1
7+,K1
INCREMENT VICTIM NO.
TEMC
P(65+P7) LT K100
YES
NO
LOOP ON 10 POSSIBLE VICTIMS-P6
Q3
P(55+P7) NE XH58
NO
YES
XH3 GT K0
NO
YES
UNLOAD VICTIM TIME
UNLOAD DEAD VICTIM TIME
EMC
FDIE
HANDLE DEAD VICTIM
TEMC
INCREMENT
XH1+,K1


Q3
XH1 GT KO
NO
YES
XH3 EQ KO
NO
YES
ERROR ROUTINE
LOGIC KEY
XH3,K1
XH1,KO
DOUT
RTURN
ETU COMM. FAC.
ETU COMM. FAC.
DISPATCHER
TIME TO TELL DISPATCHER RETURN TO SER
LEAVE QUEUES & RELEASE DISPATCHER
ETU COMM. FAC
ETU
TERMIN-ATE


H
8,K1
TREATMENT
No.
NEXT2
21,K4
4 SUPPLIES
REQ'D
REQ2
27,K5
SUPPLIES
AVAILABLE
V(V32) EQ
K0
YES
NO
V(V32) EQ
V40
YES
NO
V(V32) EQ
V41
YES
NO
LOOP ON SUPPLS
--P27
TRY
LOOP ON REQ'D
SUPPLIES
--P21
REQF
REQF
21,K3
3 FAC.
REQ'D
27,K10
10 POSSIBLE
FAC.
V38 EQ K0
YES
NO
V38 EQ V39
YES
NO
LOOP ON ER
FACILITIES
--P27
TRY
LOOP ON REQ'D
FACILITIES
--P21
VICT
TEMC


TRY
P8 GE K3
P(45+p7), K1
PI = 1
VICT2
P8,K1
NEXT2
K
XH60 EQ K0 (ASSGN PREF ER)
NO
YES
P28 EQ K0
NO
YES
K1
INITIALIZE
XH5,P4
XH1,P28
XH4,XH(V6)
XH1,X(V4)
XH9,V9
30,V6
31,XH9
29,XH1
RDISP
T4
XH75 EQ K0
NO
YES
ERROR ROUTINE
T3
ER FACILITY QUEUE
T5

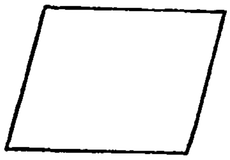

VICT
21,K3
3 FACILITIES
FLAG-FOUND FACILITY
XH75,K0
27,K10
10 FAC. AVAILABLE
V38 EQ K0
NO
YES
T3
LOOP ON REQ'D FACILITIES --P21
TERMIN-ATE
YES
V38 EQ V39
NO
LOOP ON ER FACILITIES --P27
T4
F(V36)EQ K0
V2
XH75,V36
T5
V2
ER FACILITY --F(V36)
TIME TO USE FACILITY --F(V42)
ER FACILITY
T3
--TIME
XH71,C1
P(65+P7), V43
P(MORTALITY)
TERMIN-ATE

APPENDIX B

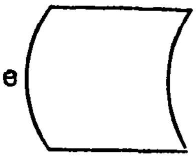
SUMMARY OF FLOWCHART SYMBOLS

B1. Summary of Standard Flowchart Symbols[1]

Input/Output

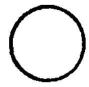


Online Storage

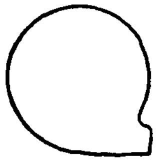


Process

Connector

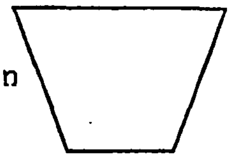


Magnetic Tape

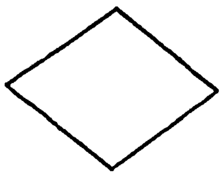


Terminal

Manual Operation



Decision



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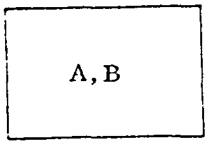
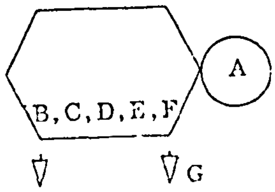
[1]USA Standard Flowchart Symbols for Information Processing. United States of America Standards Institute, N.Y., N.Y.: X3.5-1966.

B2. Summary of GPSS Flowchart Symbols[1]

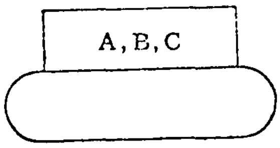
Advance



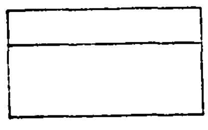
Alter



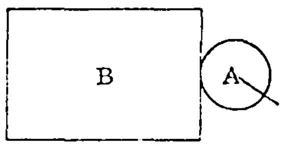
Assign



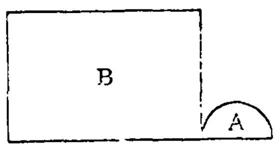
Buffer



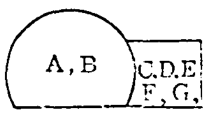
Depart



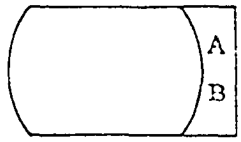
Enter



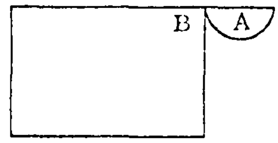
Generate



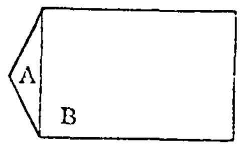
Index



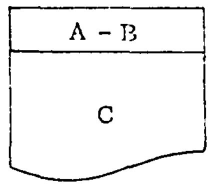
Leave



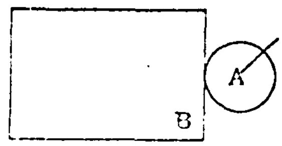
Loop



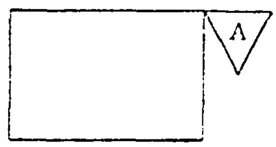
Print



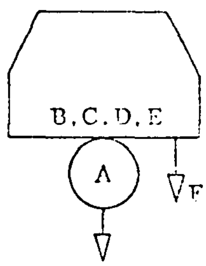
Queue



Release



Remove



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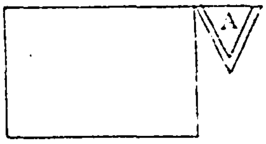
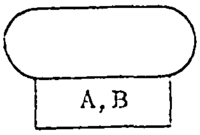
[1] <u>GPSS Users Manual</u>. IBM Corp., H20-0326-2.

B2. Continued

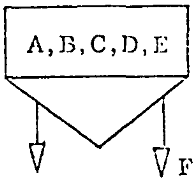
Return



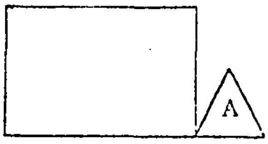
Savevalue



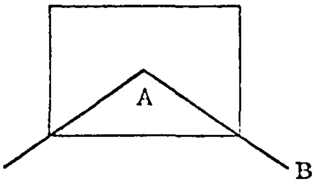
Scan



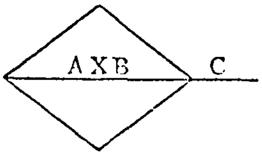
Seize



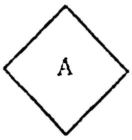
Split



Test



Transfer



APPENDIX C

PROGNOSIS CURVES

The most important contribution of the Texas Hospital Association Disaster Simulator, in the view of this research, is the development of relatively detailed prognosis curves. The details of these curves are presented below.

> Casualties have been divided into eleven injury classes; six levels of care are specified within each injury class; 3 levels of treatment personnel, two types of facilities, and five categories of supply have been defined . . . and a transition matrix has been developed which moves all or a part of the casualties in various injury classes to other injury classes so that the results of radiation injury can be studied. A mdeical prognosis was prepared for each level of care within each injury class and the prognosis data reflect the cumulative probability of a casualty being removed from the injured population as a result of recovery or mortaility at any time period [see Figure C.1] . . . . The nonavailability of supplies, facilities, and treatment personnel increases mortality or decreases recovery at specified treatment levels [see Figure C.2] . Prognosis were prepared for each injury class for a period of 60 days after the simulated disaster. . . .
> Normalized values--The mortality/recovery time-functions and supply-penalty time-functions are input data for decision-cycle programs. These functions are expressed as cumulative quantities and as such must be assessed against the beginning populations. The following normalization procedure allows the cumulative function to be normalized to a particular time period:

$$P = \frac{p\,I}{(1 - d - r)}$$

P = number of casualties who die or recover during the time period.

p = the difference between the cumulative fraction of injured who die or recover during the time period. That is, p can be either:

$$p = d_{t+1} - d_t$$

d_{t+1} = cumulative fraction who die at the end of the time period.

d_t = cumulative fraction who die at the beginning of the time period.

or p can be $p = r_{t+1} - r_t$

r_{t+1} = cumulative fraction who recover at the end of the time period.

r_t = cumulative fraction who recover at the start of the time period.

depending upon whether the quantity to be normalized is a function of the recovery fraction or the dead fraction.

I = the number of injured at the start of the time period.

d = cumulative fraction dead at the start of the time period.

r = cumulative fraction recovered at the start of the time period.[85]

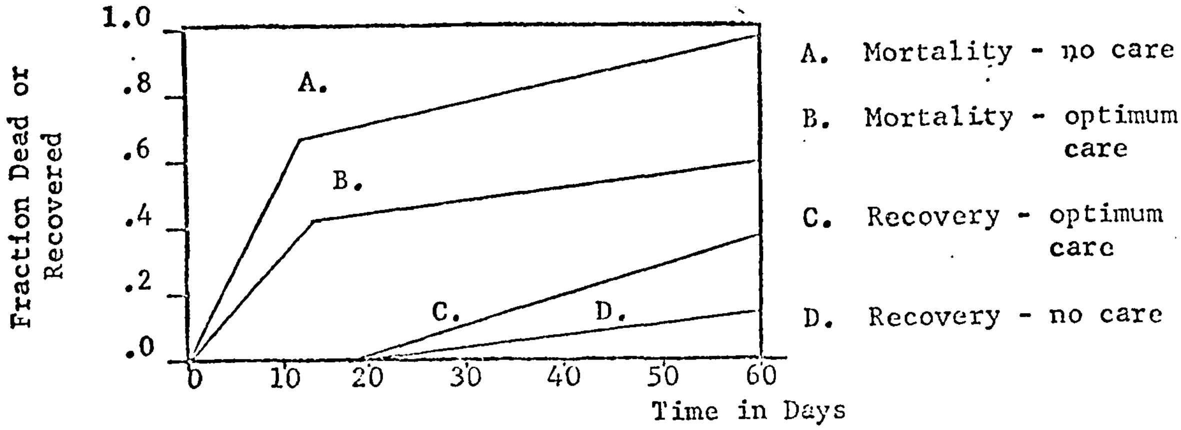


Figure C.1 Cumulative Mortality -- Recovery Functions [85]

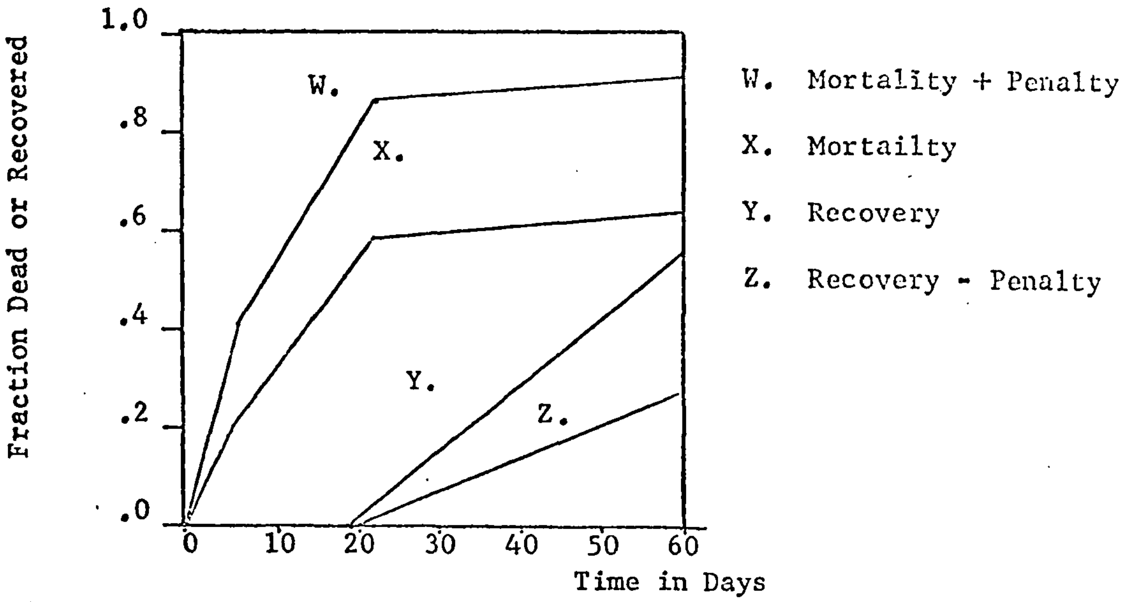


Figure C.2 Penality Effect Included in Mortality-Recovery Functions [85]

APPENDIX D

MEDICAL INFORMATION

D. 1 Emergency Room Equipment

Some of the recommended equipment for an emergency room includes:

Wall oxygen outlets (or two large mobile oxygen cylinders on carts, with reducing valves), flow meters and delivery tubes.

Two self-refilling bag-valve-mask units with oxygen reservoir tubings.

Oropharyngeal and nasopharyngeal airways of various sizes.

Suction equipment as outlined in the ambulance.

Tracheal intubation kit including equipment for gastric intubation.

Emergency drug kit.

Injection/infusion kit including needles, syringes, catheter needles, stopclocks, venotubes, administration sets, blood substitutes (e.g., dextran 40, isotonic saline solution, dextrose in Ringer's solution), blood (type O, RH negative--refrigerated), blood warmer, equipment for infusion under pressure.

Venous cut-down tray.

Separate crash cart with electrocardioscope (needle and disc electrodes), external/internal defibrillator with appropriate electrodes and battery-powered pacemaker.

Electrocardiograph.

Tracheotomy tray (all sizes of tubes, with 15 mm male adaptors; adult tubes cuffed).

Thoracotomy tray for open chest resuscitation.

Pleural drainage tray (with trocards and catheters of various sizes; Heilich valves or water seal drainage bottles).

Equipment for central venous catherization.

Equipment for arterial puncture and catherization.

Tray for nerve blocks and local anesthesia.

Trays for minor surgery (hemostasis, etc).

Ventilating bronchoscope (all sizes, available in hospital).

Blood pressure cuffs and stethoscopes.

Mechanical ventilator capable of producing assisted and controlled intermittent positive pressure ventilation with 100% oxygen, drug aerosols and heated mist, with airway pressures and tidal volumes readable. [42, pp. 599-600]

D. 2 Recommendations for Ambulance Service

(1) Communication

A dispatching office with an adequate communications system, a time recording device and adequate space for records should be set up. On all shifts, the dispatcher should have at least as much training as the ambulance personnel so that he can safely transmit reliable information as to the injury or illness.

The central ambulance dispatching officer should be allowed to select ambulance vehicles and hospitals according to the needs of the patient.

Ideally, the community should establish an "Emergency Medical Operations Center" (EMOC) for appraisal of everyday medical emergencies as well as disasters and to serve as a communications and ambulance dispatching center. It would mobilize resources outside of hospitals and direct the flow of patients. The EMOC may be operated by the local public health service under the guidance of the community council. It should be coordinated with all other emergency services controlled by the local government (eg, fire, police). The dispatching center, all ambulance and rescue vehicles, and all major emergency hospitals should be linked by two-way radiotelephone. Ambulance personnel in the field should be able to consult directly with hospital physicians via radiotelephone. The efficiency of data transmission by use of telemetry systems from the emergency scene to the physician should be explored. [42]

(2) Training and Education

Recommended Basic Training -- The ideal minimal standard ambulance attendants' training course has not been worked out as yet. However, all initial and continuing education should be under the direction of a physician, and under the supervision of a paramedical instructor.

Driver and attendants should hold a current certificate of completion of an advanced First Aid course, given by the Red Cross, the US Bureau of Mines, the St. John's Ambulance Association or equivalent.

The Red Cross first aid course is a basic requirements, but it does not constitute total adequate training. All ambulance attendants should be certified and annually recertified by a chapter of the American Heart Association, after they completed one of the AHA's courses in cardiopulmonary resuscitation. Manikin practice and periodic refresher courses can be continued under the instruction of a paramedical ambulance attendant. [42]

D. 3 Trends and Problems in the Emergency Care System

Numerous articles and studies have indicated many major trends and problems in the community ECS. Some of the more important findings are outlined below:

(1) General

Some of the general trends and problems that affect the total emergency care system are:

> Many more patients are treated in American emergency departments than are admitted to hospitals. ... Less than half of these cases are true emergencies: more than half are medical, pediatric, and obstetric problems. Surgeons still man the emergency department even though less than forty per cent of all cases are surgical or traumatic in nature. The emergency department must become the combined responsibility of all branches of the hospital staff. [40]

> The public has come to look upon the emergency department as the community medical center where any may apply, with any complaint, at any hour of the day or night, and expect prompt and courteous attention as his due. [40]

> That existing emergency departments usually constitute the weakest and most neglected link in the chain of hospital care is beyond doubt. It is equally clear that the emergency departments of most general hospitals need renovation or replacement. Few persons responsible for these changes have any valid notion of what to plan for or how to do it. [40]

> Planning for community emergency care services is not coordinated. ... To date, attempts to improve our emergency care system have been directed toward elements of the system rather than toward improvements in the total system. [46 pp. 32]

Advanced Paramedical Education -- College linked paramedical technicians' courses of about two years' duration may cover many areas of acute medicine, including emergency transportation, and assisting physicians in hospitals in inhalation therapy, resuscitation, intensive care and emergency room work. [41]

(3) Physicians and Ambulance Service

While the trend has been to remove physicians from ambulance duties, the conditions of some patients may necessitate the attention of a physician resuscitation specialist at the scene and during transportation. Trial programs are proposed with physicians staffing specially equipped, hospital-stationed ambulances or aircraft to answer special calls, including those for the elective transfer of patients who require life-support en route from one hospital to another. [42]

(4) Emergency Vehicles

An emergency ambulance is for transport with life support of one or more patients on stretchers. The emergency ambulance should have sufficient storage space for equipment used by attendants and physicians. The general features include:

(1) Separate (?) driver and patient compartments with communication between the two.

(2) Illumination adequate for medical treatment

(3) Temperature control of patient area

(4) Two-way radio capable of clear transmission and reception over the entire community service area, among vehicles, dispatching center and hospitals.

(5) Warning devices acceptable to state or local statute.

(6) Smooth riding characteristics.

Most vehicles presently in use are unsatisfactory for life support. [42]

The use of helicopters or aircraft for the transport of acutely ill and injured patients from isolated or otherwise inaccessible sites (eg, traffic congestion) and from smaller hospitals to major emergency hospitals should be developed. [42]

(2) Communication: Trends and Problems

The majority of local and regional communication systems currently in existence are inadequate to provide the control necessary for an effective emergency care service. [47]

(3) Transportation: Trends and Problems

No national standards exist for the training or qualification of ambulance attendants. [46, pp. 3/1]

Most ambulance operations in the United States are unregulated. [46, pp. 3/2]

No medical-engineering data are available to serve as a basis for design specifications for emergency service vehicles and equipment. [46]

There has been a general reluctance to enact legislation for the regulation of ambulance services. Such legislation should include licensing, personal qualifications, and standards for service. [46, pp. 3/3]

(4) Medical Treatment: Trends and Problems

There is a gap in the line of responsibility for the treatment of injured before the arrival of the victim at the emergency room. The responsibility for first aid and treatment during transit has not been accepted by anyone prior to hospital admission. [1]

Pathogenesis of deaths and injuries resulting from Highway automobile accidents is not generally known. [46, pp. 3/1]

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[1] Accidental Disease and Disability: The Neglected Disease of Modern Society. Washington, D.C.: National Academy of Science, 1966.

This present dilema of emergency care can be expected because most medical schools have done little to teach trauma beyond minimal first aid and have structured student trauma education at the house staff level. Trauma and shock, as areas of special interest, have attracted few supporters.

The hospital attitude toward this problem is one of apathy in failing to provide the auxiliary support so essential for proper care of the severly ill. Chemistry and blood gas laboratories are seldom available at night and on weekends when the incidence of accidental injury is greatest. Unavailability of proper x-rays, inadequate blood bank service, and the skeletal staffing of physicians and nurses on holidays and weekends, further handicap the experienced as well as the inexperienced physician. [53]

(5) Information Subsystem: Trends and Problems

The total treatment of injured people on the basis of existing information is inadequate in most situations. Therapy continues to fall into a pattern of guess-work because the physician is unable to study the trauma patient who fails to respond to treatment. Scientific study and observation, along with good care, are synonymous with good therapy and the right of every patient. Inability to collect scientific information on what is taking place under conditions of therapy can only result in mediocre patient care. If scientific observations are not made during this period, the experience is lost and the physician is really not accepting his responsibility to the patient for he cannot otherwise guide therapy in the direction of decreasing mortality and morbidity due to accidental injury. Would it not be better if our profession solved the problem by converting all available resources into a plan for emergency care? [53]

Organized information concerning motor vehicle accidental death and injury is not generally available. [46, pp. 3/1]

The documentation has been the forgotten subsystem within the emergency care system. [46, pp. 2/16]

APPENDIX E

TEST DATA

Description of ECPS Data Cards

```
COL1      7       1       1       * NUMBER OF 6 COLUMN DATA WORDS ON CARD
                  3       9       *      * COMMENTS/EXPLANATIONS
    VICTIM                               (IS START OF VICTIM DATA
            CALL                  0      (FIRST CARD FOR A NEW CALL
            IDNUMB                1      (ID NUMBER
            TIME                  1      (TIME OF ACCIDENT /ILL -- IN MINUTES
            NODE                  1      (NO. OF NEAREST NODE
            KEY                   4      (LOGIC KEYS -- 1 TO 4 KEYS
            ETUPEN                5      (ETU ASSIGMENT PENALTY -- 5 TYPES
            ERPEN                 5      (ER ASSIGMENT PENALTY -- 5 TYPES
            NUMVIC                2      (NO. OF VICTIMS REPORTED - ORIG. ACT
            QUEUE                 2      (FOR DISPATHER. ACC REPORT SYS
            CNEMB                 10     (CASE NO. EACH VICTIM -- MAX OF 10
            ERPREF                10     (ER PREFERRED BY EACH VICTIM -- OR 0
            TONODE                10     (USED IN PLACE OF ERPREF, WHEN GOING
                                          TO A SPECIFIC NODE
            FAC                   2      (FACILITIES FOR ACC REPORT, DISPATCH
            FUNC                  3      (FN NO FOR DETECTION, COM DLAY, RLAY
            START                 1      (VICTIM NO TO START WITH -- 1 OTHWIS
            INIT                  2      (INITIALIZE INIT(K) TO SECOND VALUE
            DELAY                 1      (DELAY TIME TO REACH NEAREST NODE
            END                   0      (NOP -- NO OPERATION
            CALL
            ETC. ...
```

```
MODEL                       0      (DATA DESCRIBING THE ECS MODEL
     CASE                   1      (BEGINNING OF CASE DATA -- CASE NO.
                                    CONTAINED IN FIRST VALUE--MAX OF 20
          EMC               0      (EMER.MED.CARE -- 3 DATA CARDS FOLLOW
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)(FAC) (TIME)(FAC) (TIME)(FAC) (TIME)
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)(FAC) (TIME)(FAC) (TIME)(FAC) (TIME)
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)(FAC) (TIME)(FAC) (TIME)(FAC) (TIME)
          FA                0      (FIRST AID -- 3 DATA CARDS FOLLOW
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)      (TIME)
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)      (TIME)
          (PI1) (PI2)
          (SUPP)(SUPP)(SUPP)(SUPP)      (TIME)
          (TAU1) (TAU2)

          FNPROG                   (FN. NO. FOR BASIC PROG. CURVE
          FNCALL            1      (FN. NO. FOR CALL ENROUTE TO ER
```

```
TYPETU               0       (ETU TYPE DATA --2 DATA CARDS FOLLOW
         (CAP) (NETW)(COMM)(QUE) (RAD)
         (SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)
ER                   0       (ER DATA -- 4 DATA CARDS FOLLOW
         (TYPE)(QUE) (COMM)(QUE) (NODE)
         (SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)(SUPP)
         (FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)
         (FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)(FAC) (NUMB)
ETU                          (ETU DATA -- 1 DATA CARD FOLLOWS
         (TYPE)(STAT)(FAC) (QUE) (NODE)(DLAY)

NETWRK               0       (NETWORK DATA -- 3 DATA CARDS
         (NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)
         (NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)(NETW)
         (NETW)(NETW)(NETW)(NETW)
KEYS                 0       (LOGIC KEYS -- 1 DATA CARD
         (KEY) (KEY) (KEY) (KEY) (KEY) (KEY) (KEY) (KEY) (KEY) (KEY)
SCOPE          XXXXXX1       (TIME SCOPE -- NO DATA CARDS
PENLTY               9       (ASSIGNMENT PENALTIES -- NO DATA CARDS
```

```
NET                                              (START OF NETWORK DATA CARDS
     NETNUM          XXXXXX          (NETWORK NO. -- 1 TO 4
      NETYPE          XXXXXX          (NETWORK TYPE -- 1 OR 2
      ARCS
           (ROW) (COL) (TIME)
           (ROW) (COL) (TIME)
           (ROW) (COL) (TIME)
              ETC.
      END
      NETNUM
      NETYPE
      ARCS
      END

*


FUNC                        1          (FUNCTION -- (FN. NO)-- DESCRIPTION
FACLTY
      (NO.) (TYPE)          (DESCRIPTION -- E.G., ETU NO. 5            )
      (NO.) (     )
      ETC.
SUPPLY
      (NO.)                 (DESCRIPTION
      ETC.
QUEUE
      (NO.)                 (DESCRIPTION
      ETC
C                           (COMMENT CARD -- COMMENTS IN COL. 7-72
```