SIMULATION OF A COORDINATED ACCIDENT RESCUE SYSTEM

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Summary

Project CARE-SOM (Coordinated Accident Rescue Endeavor-State of Mississippi) was a 15-month study of emergency medical evacuation systems for the National Highway Safety Bureau, U.S. Department of Transportation. The object of the project was to develop, demonstrate, and evaluate an integrated system for emergency medical evacuation. The system contained existing ground ambulance services, expanded communication abilities, and helicopter ambulance units. This paper describes a simulation of the experimental system used to evaluate rescue performances under various helicopter dispatching decision rules. The simulation language is GPSS/360.

Introduction

The objective of Project CARE-SOM was to develop, demonstrate, and evaluate a comprehensive and integrated system for emergency medical service consisting of transportation, treatment, and communications which could be expanded into a statewide plan to provide these services on a uniform, coordinated, and prompt basis. As a part of this study, a simulation of the rescue system was written. The basic idea of this project was to develop and evaluate a coordinated rescue service, integrating helicopter ambulances with supporting ground ambulances by use of a coordinating communication system. After a five-month planning and preparation period, a six-month operational period began on November 1, 1969. Three contract helicopters (Fairchild-Hiller FH-1100) were used, with each operating in a different zone having a 50-mile radius. About 50 percent of Mississippi was covered (see Figure 1). Each helicopter was on alert status during 14 hours each day.

The project was administered by the Engineering and Industrial Research Station of Mississippi State University. Local zone managers under contract with Mississippi State coordinated the operations at the local level in each of the operational zones. The Governor's Highway Safety Program served in an advisory capacity.

The basic operating procedure was as follows. An accident would occur, and notification would come in to the highway patrol, Project CARE-SOM zone headquarters, a participating ground ambulance service, or a local law enforcement agency. The helicopter pilot and medical attendant would be notified and the helicopter dispatched simultaneously with a ground ambulance toward the accident. Radio communication between the helicopter and law enforcement agents at the scene served to guide the helicopter in and coordinate rescue efforts. After rendering first aid as needed, victims would be loaded and flown to the hospital. During this flight, radio communication between the helicopter and the hospital served to pass medical information and prepare the hospital to receive the victim(s). Additional radio communication between the helicopter and ground ambulances served to coordinate ambulance utilization.

The Simulation Model

The purpose of the simulation model was to allow evaluation of the coordinated rescue system under different operating conditions and rules. Some of the different conditions tested will be discussed later in this paper.

The model was written in GPSS/360. This language was chosen for its flexibility and the ease with which queuing situations can be modeled. This is appropriate because a highway rescue system can be viewed as a queuing system, treating accident occurrences as customer arrivals competing for inter-related service facilities.

The block diagram of the model is shown in Figure 2. This diagram is for the model of the system as it existed during the operational phase of the project.

As shown in the diagram, the model operation consists of generating accidents at the proper frequency according to time of day and day of week and forcing the system to handle the accident in a stochastic fashion which reflects the statistics collected during the CARE-SOM operation period, as well as historical records obtained from the Mississippi Highway Patrol. By identifying each ambulance service in the model as well as the locale for each accident, response times, local travel times, and other parameters are forced to fit the appropriate description, increasing the ultimate accuracy of the model.

The system simulated is as described elsewhere in this paper. There are three helicopter rescue units, together with more than 50 privately and semi-privately operated ground ambulance services for the three zones. In addition to the traffic accident rescue missions, the helicopters fly for other medical emergencies and for critical inter-hospital transfer missions.

The operation of the model follows the diagram. An accident is generated, described, and tested to determine whether the primary call is to a ground ambulance or a helicopter. If to a helicopter, travel times are calculated and recorded, based on an (x,y) coordinate location of the accident. If to a ground ambulance, a travel time is recorded which is consistent with the distribution of accidents appropriate for the accident locality selected. Records are suitably updated; and consideration of the accident in question is terminated.

Interpretation of Results

For the convenience of the user, the significant output from the program is structured by an output editor. The ground ambulance services are identified by the corresponding service number as shown in the storage definitions of the program. For the edited statistics, on other ground missions, the service number shown corresponds to the service number above plus 60.

The edited description of helicopter missions is broken into four parts, traffic accidents, other medical emergencies, inter-hospital transfers, and a calculated percentage response of helicopters. In each of the first three categories the statistics are arranged in the following order: Rescue I, Rescue II, and Rescue III (Northern, Central, and Southern zones respectively).

For the user who wishes further information, the standard GPSS/360 output is also printed. The edited statistics described above are contained in the queue statistics, as indicated in Table 1.

In the edited output, the column labeled "Calls Refused" indicates the number of calls in each category of service which could not be answered because of the helicopter in question already being on another mission. Then the number of calls actually answered is the difference between "Total Calls" and "Calls Refused." "Average Time/Mission" was calculated to include time to the scene plus time at the scene plus time to the hospital. Time to return to the operational base is not included. A warmup time of one minute is included in each helicopter mission. Since this action is usually performed during the notification period (the pilot warms up while the attendant takes down directions), the average time/per mission shown can be taken as elapsed time from notification until the patient arrives at the hospital.

While the statistics for simulated helicopter operation are significant and relatively dependable, less dependance should be placed on the statistics for the ground ambulance services. This is primarily due to the difficulty of obtaining reliable data on the operations of these services. Simulated operation reflects reported (observed) operation. Examples of data for ground services which were difficult to obtain are:

(1) How many services in each area service accidents?

(2) For those funeral services also responding to accident calls, how many funerals do they service per time period and how long does a funeral take (the length of time the unit is unavailable for accidents)?

(3) What is the nature of other demands on the ground units and what is the frequency of these demands, <u>for each ground service included</u>?

In order to make the model as realistic as possible answers to these questions were approximated by data gathered from a limited number of services. However, because data were approximated, the results of the simulation should not be interpreted as strictly accurate for any specific ground service, but the overall data presentation may be used as an indication of the general nature of ground service responses.

Runs of the Simulation Program

The model was used to simulate three different rescue systems. Each run was for a simulated six-month operational period. These runs were:

(1) The system as operated during the six-month period.

(2) The idealized system where the helicopter responds to each accident where it has a time advantage.

(3) The idealized system where the helicopter is called first for each accident.

The helicopter data from each of the three runs is shown in Tables 2, 3, and 4, respectively.

The first of these runs was for validation purposes. Table 5 shows a comparison of results from the validation run and actual results as reported during the operational period. The chief differences between the runs are in average mission time. This is caused by a real difference in the way the simulated system works as compared with the real system. In the simulation model, the helicopter always flies directly to the scene and lands with no hesitation. After picking up the victim, the simulated helicopter always flies directly to the nearest hospital, regardless of which hospital this is, and lands with no hesitation. This represents a difference from the real system, where there can be hesitations, delays, and delivery to a hospital different from the closest. Also, some of the difference is in the nature of the simulation technique, i.e., no six-month operation of the system will yield exactly the same results.

The second run is based on an analysis of response times of helicopters verses ground ambulances. This analysis for each of the three zones led to "time response contour maps." In brief, these maps indicate, by shaded areas, all locations where the ground ambulance can respond to an accident more rapidly than a helicopter, and by unshaded areas, all locations where the helicopter can respond to an accident more rapidly than a ground unit. Naturally, the shaded areas tend to cluster around ground ambulance locations, with the clusters becoming larger as the areas are more remote from the helicopter base.

Based on a sample of 300 accidents from 1968 accident data, 30.1 percent of all accidents occur at a location where the helicopter has a faster response than any ground ambulance service. This sample is based on located accidents, and is consequently biased, since accidents occurring in cities are less likely to be located than those outside. Therefore, this 30.1 percent figure should probably be treated as an upper limit. This figure is an average for the three zones. The figures for each zone (sample size 100) are shown in Table 6.

As shown in Table 3, the helicopter was able to respond to 23.3 percent of the accidents, when actually called for 30.1 percent of the time. Interestingly, the Average Time Per Mission increased from 17.9 minutes to 24.8 minutes, an increase of about 38 percent. This is due to the change in locations of simulated accidents from the first run to the second. The first run located accidents as reported during CARE-SOM operation, the second according to the sampled 1968 data. The increase is caused by the fact that during the system operation, most accidents for which the helicopter was called were located fairly close to the CARE-SOM site; the helicopter was not often used for accidents distant from the CARE-SOM site.

The third run was an attempt to find some limits to the operational capabilities of the system. The appropriate helicopter was called first for every accident. If it was busy, a ground ambulance was dispatched.. The assumption was built into the program that the helicopter could land at the scene of any accident.

During the simulation run, the helicopters were actually able to respond to 69.0 percent of the calls received. The Average Time Per Mission increased again, from 24.8 minutes to 29.1 minutes, this time due to the calls at the edge of the zones which the helicopters were forced to service. The locations of the accidents were based on the sample of 1968 data previously mentioned.

Conclusion

As a result of the effort described in this paper, there was an increase in the available data concerning operating capabilities of the system being researched. In effect, the three runs described extended the operational period of the project from six months to 18 months, and allowed evaluation of at least one system which would have been impossible under any easily imaginable set of circumstances. Considering that the cost of establishing and operating the real system for six months approached one million dollars, the additional twelve months of simulated operation was a real bargain.

In addition the final research report carried a copy of the simulation program and detailed instructions for modification so that completely different coordinated rescue systems can be modeled, using the existing program. This is an extra bonus of the sort which the simulation technique customarily offers, explaining at least in part the reasons for the growth in use of this tool.

TABLE 1

QUEUES	CONTAIN STATISTICS ON
1-55	GROUND AMBULANCE RESCUES
56	NORTHERN ZONE HELICOPTER ACCIDENT RESCUES
57	CENTRAL ZONE HELICOPTER ACCIDENT RESCUES
58	SOUTHERN ZONE HELICOPTER ACCIDENT RESCUES
61-115	OTHER GROUND AMBULANCE MISSIONS
116	NORTHERN ZONE INTER-HOSPITAL TRANSFERS
117	CENTRAL ZONE INTER-HOSPITAL TRANSFERS
118	SOUTHERN ZONE INTER-HOSPITAL TRANSFERS
119	NORTHERN ZONE OTHER MEDICAL EMERGENCIES
120	CENTRAL ZONE OTHER MEDICAL EMERGENCIES
121	SOUTHERN ZONE OTHER MEDICAL EMERGENCIES

TABLE 2

SIMULATED SYSTEM AS OPERATED BY CARE-SOM

ACCIDENTS	TOTAL CALLS	CALLS REFUSED	AVG. TIME PER MISSION
RESCUE I	44	4	20.1
RESCUE II	106	2	14.4
RESCUE III	61	2	22.6
OTHER MEDICAL EMERGENCIES			
RESCUE I	16	3	18.5
RESCUE II	33	4	12.2
RESCUE III	36	2	20.8
INTER-HOSPITAL TRANSFERS			
RESCUE I	97		119.2
RESCUE II	59		118.4
RESCUE III	60		115.4

THE HELICOPTER WAS ABLE TO ANSWER 11.3% OF ALL CARE-SOM ZONE ACCIDENTS DURING THE FOURTEEN HOUR OPERATIONAL PERIOD.

TABLE 3

SIMULATED SYSTEM - HELICOPTER RESPONDS IF IT HAS A TIME ADVANTAGE

ACCIDENTS	TOTAL CALLS	CALLS REFUSED	AVG. TIME PER MISSION
RESCUE I	114	14	23.0
RESCUE II	228	21	26.5
RESCUE III	128	13	23.7
OTHER MEDICAL EMERGENCIES			
RESCUE I	14	4	24.0
RESCUE II	36	5	26.0
RESCUE III	36	4	22.0
INTER-HOSPITAL TRANSFERS			
RESCUE I	112		129.0
RESCUE II	48		144.9
RESCUE III	67		120.0

THE HELICOPTER WAS ABLE TO ANSWER 23.3% OF ALL CARE-SOM ZONE ACCIDENTS DURING THE FOURTEEN HOUR OPERATIONAL PERIOD.

TABLE 4

SIMULATED SYSTEM - HELICOPTER RESPONDS TO ALL ACCIDENTS

ACCIDENTS	TOTAL CALLS	CALLS REFUSED	AVG. TIME PER MISSION
RESCUE I	488	98	28.6
RESCUE II	749	155	29.3
RESCUE III	491	72	29.3
OTHER MEDICAL EMERGENCIES			
RESCUE I	16	4	25.9
RESCUE II	29	3	31.1
RESCUE III	38	4	28.2
INTER-HOSPITAL TRANSFERS			
RESCUE I	103		126.2
RESCUE II	56		126.3
RESCUE III	40		125.0

THE HELICOPTER WAS ABLE TO ANSWER 69.0% OF ALL CARE-SOM ZONE ACCIDENTS DURING THE FOURTEEN HOUR OPERATIONAL PERIOD.

TABLE 5

	VALIDATION RUN		REPORTED RESULTS 11/1/69 to 4/30/70	
ACCIDENT MISSIONS	NO.	AVG. TIME	NO.	AVG. TIME
RESCUE I	40	20.1	38	
RESCUE II	104	14.4	99	
RESCUE III	61	22.6	45	30.3
OTHER MEDICAL EMERGENCIES				27.8
	NO.	AVG. TIME	NO.	34.4
RESCUE I	13	18.5	16	
RESCUE II	29	12.2	38	
RESCUE III	34	20.8	37	
INTER-HOSPITAL TRANSFERS				
	NO.	AVG. TIME	NO.	AVG. TIME
RESCUE I	97	119.2	76	96.3
RESCUE II	59	118.4	47	76.6
RESCUE III	60	115.4	50	89.9

TABLE 6

PERCENTAGE OF ACCIDENTS FOR WHICH THE HELICOPTERS HAVE AN ADVANTAGE, BY ZONES

ZONE	PERCENT	90% CONFIDENCE INTERVAL
NORTHERN	36	36 ± 7.9%
CENTRAL	30	30 ± 7.5%
SOUTHERN	26	26 ± 7.2%

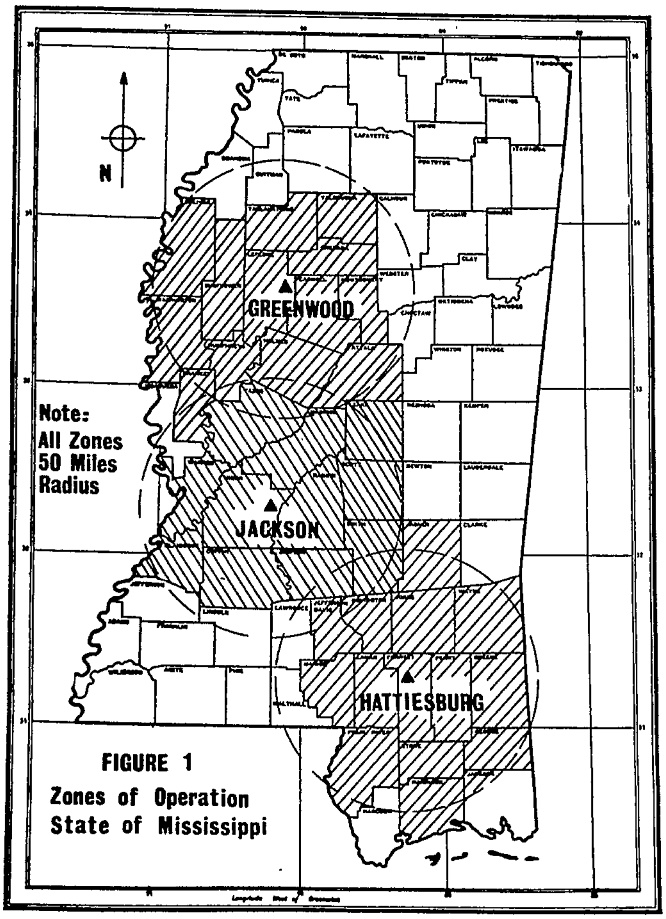

FIGURE 1
Zones of Operation
State of Mississippi

FIGURE II
FLOW CHART OF THE CARE-SOM SIMULATION