An Assessment of Emergency Response Vehicle Pre-Deployment Using GIS Identification of High-Accident Density Locations

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On average, over 15,000 crashes occur daily in the United States, most of which involve only damage to property. However, for crashes that involve injury, response time is critical. Ideally, if a specific accident location could be accurately predicted beforehand, an emergency vehicle could be dispatched before the accident occurs. Although this is not possible, the identification of high-accident locations using historical crash trends might allow the positioning of response vehicles so as to minimize the expected travel time to incidents. This paper summarizes research to identify the potential benefits of emergency vehicle pre-deployment. This research uses point location data from Iowa's Accident Location Analysis System (ALAS) for the period 1990-1995 to generate maps of high accident locations for Des Moines, Iowa. The emergency medical service facilities will be used in conjunction with the roadway network to determine the service areas of the existing facilities. The recommended location/allocation of emergency response vehicles will be determined using the power of a Geographic Information System (GIS). The network analysis capabilities of GIS will be used to estimate the response times of strategically placed emergency vehicles; this will be compared to actual response times. Key words: response time, crash analysis, GIS, EMS.

INTRODUCTION

It is well known that EMS response time is critical in traffic crashes involving injury. Emergency medical service planning involves decisions from both strategic and tactical viewpoints. Strategic decisions involve the location and number of vehicles to attain overall system goals. Tactical decisions involve responses to situations that arise given a fixed number of vehicles (*1*).

Response time is crucial to the survival of many traffic accident victims. In a potentially fatal accident, the time of starting an intravenous drip (IV) is often imperative to the survival of the victim (*2*). Additional basic life support may also be needed soon after the crash to increase the chance of survival (*3*). All factors that might increase response time are matter of concern. Some variables related to response time include land variables, such as differences in travel time and terrain between rural and urban settings, and road variables, such as variations in traffic flow related to time of day, weather, and congestion (*3*).

Various government policies have encouraged the combination of hospital accident and emergency departments into centralized units, responsible for large geographic areas. While this provides an improved quality of medical care, travel time to a crash scene is often compromised for those not near these centralized locations (*4*). According to Brown, there is a positive association between ambulance delay and the ratio of fatal to serious injuries. This study found an increased mortality rate in counties that had a low population density, further suggesting a link between elevated response time and prognosis (*5*). Numerous other studies have also demonstrated the relationship between decreases in response time and corresponding decreases in mortality (*1*).

RURAL AND URBAN RESPONSES

Emergency calls generate different approaches to providing service for individuals in need. This is evident in analyzing the difference in response hierarchy in rural and urban settings. Response characteristics vary by geographic area. Rural areas provide service to a large geographic area with limited resources (*6*). Optimal strategic location of facilities is a key element in meeting rural emergency response needs (*6*).

With higher population densities, urban areas may consolidate services from a limited number of locations. Simultaneous requests for service are also more commonplace in urban settings. Therefore, the positioning of such facilities should provide efficient service to a diverse area.

TYPICAL EMS SYSTEM

The typical EMS service response is shown in Figure 1. A communication center operator receives a request for service, usually by phone or two-way radio. The operator makes an initial screening to determine if an ambulance should be dispatched and what particular response code should be used (if needed). Next, the dispatcher assesses the geographical location and the availability of the fleet based on the particular assignment hierarchy established by the management. It is a generally accepted rule to send the closest unit to the incident. At this point the appropriate crew is

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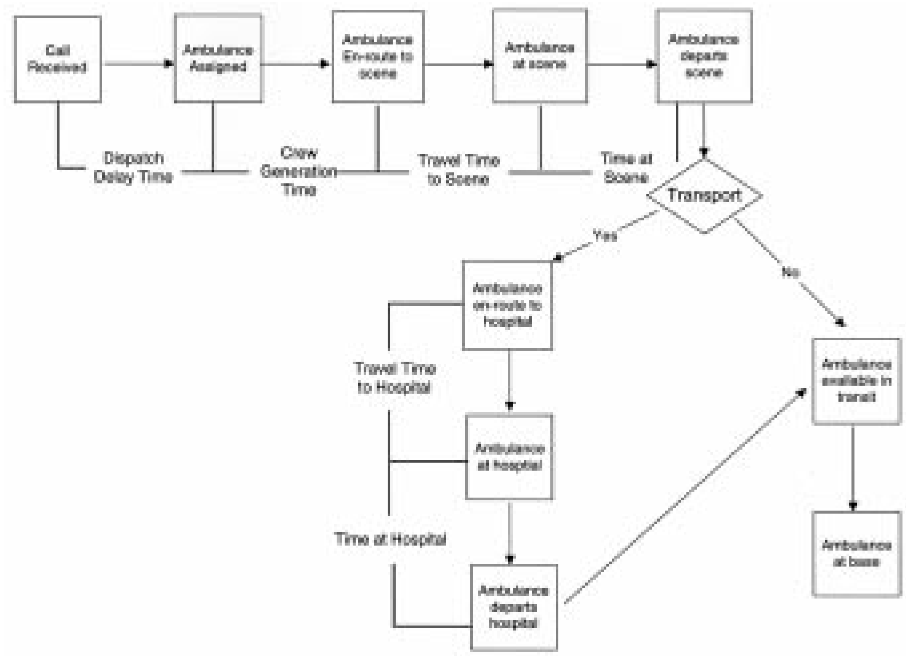

FIGURE 1 The EMS process.

assigned to respond. The time elapsed during this phase is referred to as the dispatch delay.

The response unit gathers any necessary equipment that may not be resident on the vehicle and proceeds to the specified location. The interval between the time the response unit receives a call to the time the response vehicle is in motion is called crew generation time (however, some operations include this as part of the dispatch delay).

The travel time is the time elapsed from the initial movement of the vehicle until the dispatcher is notified of the arrival. The total system response time is represented by the time interval between the call notification and the arrival on the scene. However, it is common for EMS systems to view response time delay without the dispatch delay, not taking into consideration the factors external to the mobilization process.

Dispatchers usually decide if an ambulance needs to be deployed. This does not occur in all cases. At times the necessity of an ambulance cannot be determined until notification from police or other responding units arrive at the scene. Often a short time is spent on the scene because the service is not needed or the victim refuses medical attention or transportation. When this occurs the crew departs and heads back to the base. During the time in transit back to base the unit is available to respond to another call if needed; however this does not occur often and when it does it is usually in large cities during peak hours (7).

In cases where medical attention is deemed necessary, the crew determines the appropriate medical facility that can best address the needs of the individual. After arriving at the hospital, the patient is transferred to the hospital staff. Before returning to duty, the EMS crew spends additional time completing reports and cleaning and resupplying the ambulance unit. After these steps have been completed the crew returns to their base location. The total service time is the time elapsed from the reception of the initial call to the unit's departure from the hospital.

SERVICE GOALS OF EMS SYSTEMS

EMS service has several goals in urban areas; the level of service sought by EMS planners is to have 95% of the daily demand for service be within 10 minutes (*8*). However, this level of service is not usually attained. Louisville, Kentucky, for example, responded to only 84% of the calls within the 10-minute specification (1). In general a reachable goal of an EMS station is responding to 90% of all calls in less than 10 minutes (*9*).

The level of service in a given region depends on the spatial distribution of EMS facilities as compared to the spatial pattern of the demand. EMS facilities located near areas with high demand, like crash densities, while not neglecting other areas can provide lower response times and improved levels of service and final outcomes. A geographic information system (GIS) can be used to identify existing EMS service areas, to compare these areas with traffic crash patterns, and to generate strategies to improve EMS services. The next section uses EMS facility and traffic crash data for the City of Des Moines and Polk County to illustrate the use of GIS in assessing existing EMS response patterns and the potential impacts of alternative locations of EMS facilities.

GIS-ALAS

The Iowa Department of Transportation, with assistance from the Center for Transportation Research and Education at Iowa State University, has developed a Geographic Information System Acci-

FIGURE 2 Graphical representation of crash locations.

dent Location and Analysis System (GIS-ALAS). The system, an extension of Iowa's DOS based PC-ALAS, includes the location of all crashes on all roads in the state for the last ten years, approximately 700,000 accidents. It provides spatial displays of accidents and allows the database to be queried and analyzed.

This can provide information on the locations of high-density accidents. Each accident contains up to three files (accident, driver, and injury) that provide information about the accidents that occurred. The database contains injury severity and time-of-day information. Data is also available about the roadway, including average daily traffic (ADT), lane width, length of each segment, and speed limit. These files have been created allowing a GIS to provide a spatial graphic of crash locations.

Historical trends can provide information on high accident density locations. Historical information can be beneficial to a number of users including engineers, planners, and law enforcement and emergency medical service personnel. Emergency medical services can use this historical accident information to determine the characteristics relevant to vehicle crashes involving injuries. The remainder of this paper will examine high-density locations in Des Moines, Iowa and compare response service areas from static facilities, exploring the potential for pre-dispatching in areas of need for locations that do not have adequate service.

LOCATING HIGH ACCIDENT AREAS

In GIS-ALAS, the roadway is represented as a link-node system. There are approximately 226,000 node locations throughout the State. Each accident is located with respect to two nodes, the reference and direction nodes, and the corresponding distance from the reference node. This system provides easy representation of accident density by visually displaying the accident locations with respect to the nodes.

The database was queried to determine the number of accidents associated with each reference node. The total number of accidents associated with each reference node was calculated and incorporated with the accident database. This allows the number of accidents at each reference node to be visually displayed within the GIS, the larger the dot the increased frequency of accidents. (Figure 2).

Inspection of the Des Moines metropolitan area identified accident locations based on five years of crash data (1991-1995). The objective of locating these crashes was to determine if pre-dispatching emergency vehicles would provide benefits to crash victims by reducing EMS response time. The time intervals were used to determine the peak period of crash occurrence for the metropolitan areas. These crashes were then examined based upon time of day. The a.m. peak period for crashes was determined to be from 6:30 – 9:00, while the afternoon peak period was 3:30 – 6:30. These intervals had 13% and 26%, respectively, of the total crashes within the metropolitan area for the five years of data provided.

The determination of the high crash locations provides useful information regarding the geographic characteristics of the crashes. However, other information can also be obtained including the number of injuries and fatalities. As stated, at times the necessity of an ambulance unit cannot be determined until an EMS unit is present at the scene (*7*); therefore, accidents that involve non-injuries are also important to EMS providers, as well as the crash victims.

SERVICE AREAS

Using the analytical capabilities of the GIS, the response times from each EMS location can be computed and graphically displayed to determine if service to particular areas is satisfactory. The locations of the EMS facilities were added to the GIS using data from the Iowa Department of Public Health (Figure 3). The roadway

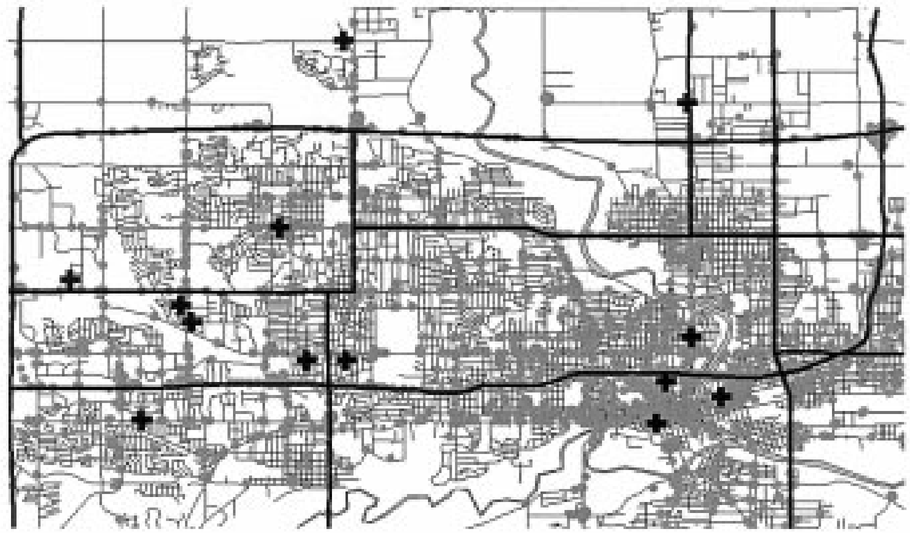

FIGURE 3 EMS locations with respect to traffic crashes within the Des Moines metro area.

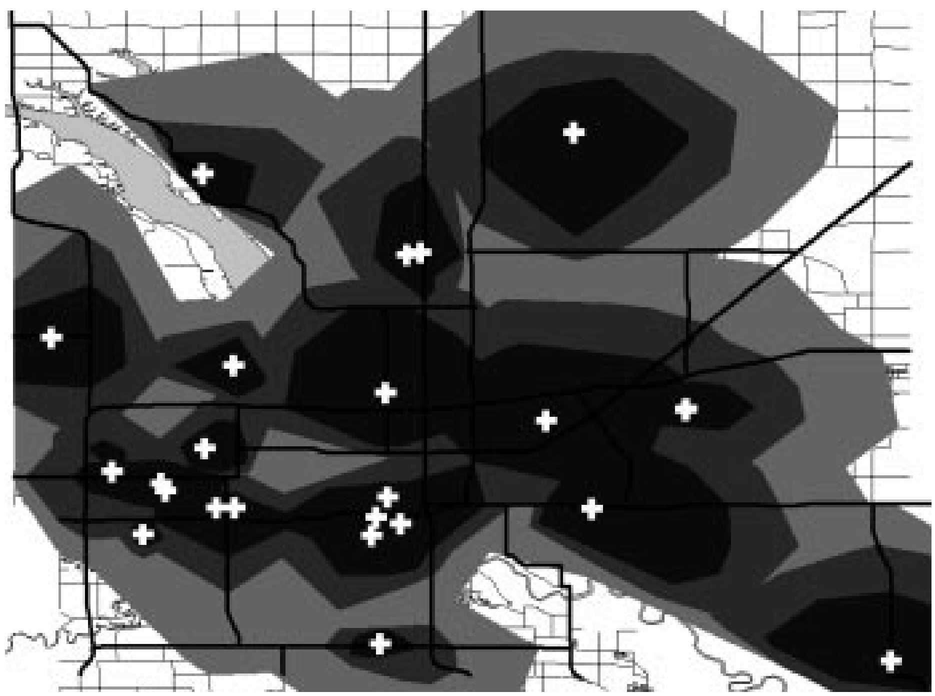

FIGURE 4 EMS travel ranges (5, 7, and 10 minutes).

files were obtained from the Iowa Department of Transportation Office of Cartography; attribute information was also used to enhance the data set.

Segment length and speed limit are used to compute a travel time for road links. This provides each individual segment with a travel time value; however, this value is only an approximation. This value does not take into consideration time delays associated with traffic control and traffic congestion.

RESULTS

Travel time areas from each of the facilities were computed and are displayed in Figure 4. The rings around the facilities indicate the areas, and accidents, that can be reached within 5, 7, and 10 minutes. Several facilities are located in clusters in close proximity to each other, especially in downtown Des Moines and in the western suburbs. Neighborhoods near these clusters are located within over-

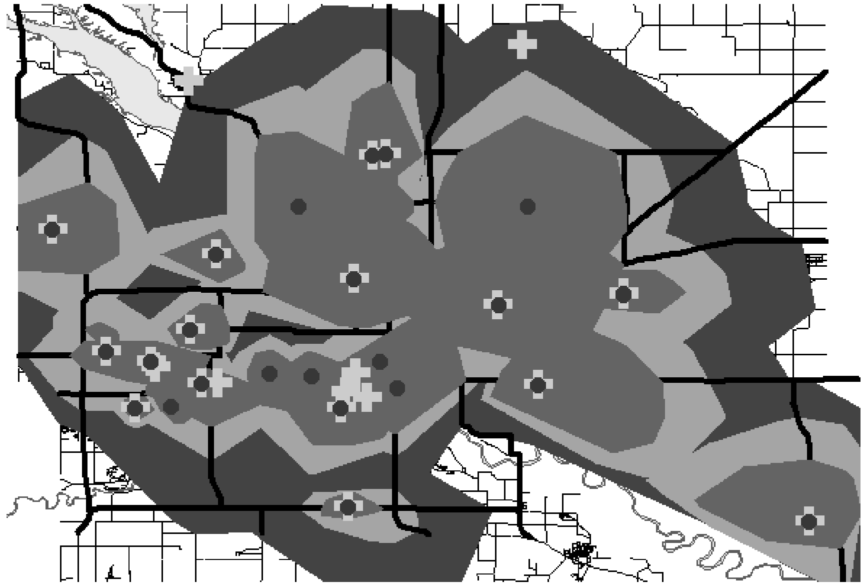

FIGURE 5 EMS pre-dispatched locations and the service areas.

Table 1 Response During AM Peak Period (Current EMS Locations)

	Total Crashes	%	Fatal Crashes	%	Injury Crashes	%	Number Injured	%
5 Minutes	4356	56.4	4	33.3	1429	55.3	1902	54.9
7 Minutes	6330	81.9	9	75	2076	80.3	2776	80.1
10 Min.	7320	94.7	11	91.7	2411	93.2	3241	93.5
Total	7729		12		2586		3467	

Table 2 Response During PM Peak Periods (Current EMS Locations)

	Total Crashes	%	Fatal Crashes	%	Injury Crashes	%	Number Injured	%
5 Minutes	9245	58.7	18	50	3186	53.7	5027	57.9
7 Minutes	13124	83.3	24	66.7	4932	83.2	7132	82.2
10 Min.	15131	96.1	33	91.7	5714	96.4	8329	96
Total	15752		36		5928		8679	

lapping 5-minute service areas of several facilities. In contrast, areas in the county's periphery tend to be in the 10-minute service area or beyond. (The results may be partially affected by data limitations related to the connectivity and characteristics of the road network.) Service area maps like Figure 4 can be used to provide an initial indication of countywide EMS coverage and identification of potentially underserved areas.

These response areas were broken further down into one-minute intervals to estimate the number of crashes occurring during each response-time interval. This was then used to determine the average response time for the entire region. The estimated average response time, given the locations of 1991-1995 crashes and EMS facilities, for the a.m. and p.m. peak periods is 4.91 and 4.92 minutes, respectively, for the Des Moines metropolitan area.

The locations of the facilities were moved in GIS to simulate possible changes in EMS activities, such as pre-dispatching vehicles to areas with high crash densities. These areas were based upon historical crash patterns identified using GIS-ALAS. (The differences in the facility locations can be found in Figure 5.) The resulting changes in service areas and response times were computed and compared to the current situation.

The overall response time for the pre-dispatched vehicles was 0.4 minutes (24 seconds) lower for both the a.m. and p.m. periods. In practice, this difference may be insignificant for most crash outcomes but critical for others. The change in facility location also resulted in an increased percentage of crashes reached within the 5-minute threshold — 56.4% before the change vs. 63.2% after for a.m. crashes, and 58.7% vs. 65.8% for p.m. crashes, about a 7% improvement for both time periods (see Tables 1-4). This benefit decreases at the 7-minute threshold (about a 2% improvement), and at the 10-minute threshold the percentage of crashes reached is roughly the same for both sets of EMS facility locations. Figure 6 further illustrates the shift toward shorter response times. Data for injury crashes and the number injured show similar patterns. (The

Table 3 Response During AM Peak Periods (With Pre-dispatched Locations)

	Total Crashes	%	Fatal Crashes	%	Injury Crashes	%	Number Injured	%
5 Minutes	4884	63.2	4	33.3	1604	62	2138	61.7
7 Minutes	6482	83.8	8	66.7	2111	81.6	2823	81.4
10 Min.	7302	94.5	11	91.7	2412	93.3	3243	93.5
Total	7729		12		2586		3467	

Table 4 Response During PM Peak Periods (With Pre-dispatched Locations)

	Total Crashes	%	Fatal Crashes	%	Injury Crashes	%	Number Injured	%
5 Minutes	10360	65.8	22	61.1	3901	65.8	5557	64
7 Minutes	13421	85.2	24	75	5040	85.2	7312	84.2
10 Min.	15129	96	32	88.9	5712	96.3	8315	95.8
Total	15752		36		5928		8679	

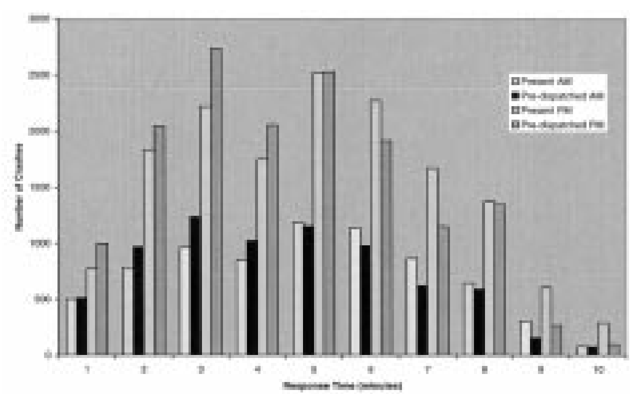

FIGURE 6 Changes in AM response times due to pre-dispatching units.

number of fatalities was too small to provide significant comparisons.)

CONCLUSIONS

The ability of EMS personnel to quickly reach crash sites is a critical determinant of final crash outcome. Response times are closely linked to the locations of EMS facilities in relation to the locations of crashes. GIS can be used to assess existing service areas, to identify potentially underserved areas, and to evaluate the implications of potential changes in EMS systems. The case study presented here illustrates that changing the location of EMS services, such as through the pre-deployment of vehicles, can result in improved response times. The benefits, in terms of improved outcomes, and costs associated with this strategy is an issue for future research.

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