Transactions on Ecology and the Environment vol 24, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

An evaluation of emergency preparedness for hazardous materials transport

Emelinda M. Parentela[a] & Shashi K. Sathisan
[a]*Civil Engineering Department, California State University, Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840-5101 USA Email: parent@engr.csulb.edu*
[b]*Transportation Research Center, University of Nevada, Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-4015 USA Email: shashi@ce.unlv.edu*

Abstract

This paper presents a methodology for evaluating emergency preparedness for hazardous materials transportation. Emergency preparedness is measured in terms of response times, number of response units, and capabilities of initial responders. The first responder to an accident could be the police, highway patrol, ambulance, or fire units. The analysis involves identification of emergency response units, and their locations, determination of service zones, and evaluation of response capability. Knowledge of the capability of the response units is useful not only for evaluating units requiring capability upgrade but more importantly, for identifying specialized units for deployment.

An analytical tool using a Geographic Information System (GIS) programming environment is presented to evaluate emergency preparedness. An example analysis for Clark County, Nevada, U.S.A. is presented in this paper. Results of the analysis permit development of strategies for allocation of resources such as establishing locations for new response units, improving the capabilities of existing ones, and providing mobile stations at critical areas.

1 Introduction

In a 1991 conference on high level waste materials, Abkowitz, et. al. [1] noted that emergency response is becoming a dominant area of concern in hazardous materials (HAZMAT) transportation and that is should be considered in risk analysis. The ability to provide timely and effective response depends on a community's emergency preparedness. Emergency preparedness relates to the ability to provide adequate and timely response in order to contain the site or minimize/mitigate the consequence of an event, such as an accident or incident, involving HAZMAT. Emergency preparedness is recognized as one way of minimizing the consequences of events after they occur, and in minimizing community vulnerability (Rowe [2]).

A methodology using the Geographic Information Systems (GIS) technology is presented to evaluate the emergency preparedness of a community. The methodology utilizes spatial databases such as the street network, location of emergency responders and an inventory of their resources, and population distribution representing the area(s) of interest. This tool helps identify the affected population along the potential routes, segments which can be serviced by multiple response units, and critical segments which cannot be reached by a response unit within reasonable response period.

2 Emergency preparedness analysis

Some of the basic issues concerning emergency preparedness of a community include questions on who are the emergency responders, where are they located, what types of training do they have, how long it would take a responder to arrive at the scene of an event, and what are the resources available to the responders (Parentela, et.al [3]).

Emergency preparedness is evaluated using various criteria such as the number of response units, response times, and station response capability in order to measure the effectiveness of an emergency response. The station response capability is evaluated based on the availability of personnel and their training level, availability of personal protective equipment, and availability of general control equipment. A description of these criteria is presented below.

2.1 Number of Response Units

The number of response units contributes to an effective response in terms of minimizing the time to complete response operations such as identifying the hazard, establishing hazard zone, isolating the scene, initiating containment techniques, attending to the injured, and others. For a single response unit the time required to complete an operation upon arrival at the scene is influenced by the severity of an event and the number and complexity of tasks to be performed. With the presence of multiple units, the tasks can be delegated to individual units thus greatly reducing the time required to complete response operations.

2.2 Response Time

Response time refers to the time elapsed between the identification of an event and the arrival of a response unit. This could be expressed as :

$$RT = TC + TD + TT \quad (1)$$

where:

- RT = response time
- TC = time elapsed between the occurrence of an event and the call for a dispatch
- TD = time elapsed between the call for a dispatch and the assignment of an emergency response unit
- TT = time to travel form the base location of the unit to the scene of an event

The United States Federal Highway Administration (USFHWA[4])hazardous material routing guide recommends a 10-minute response window as the basis for evaluating response times.

2.3 Station Response Capability

The capability of a response station is influenced by various factors including personnel availability, personnel training, personal protective equipment and general control equipment. An evaluation of the station's response capability is very useful in selecting a unit that will match the required level of response to an event. A mathematical equation representing the station response capability of a single unit could be expressed as (Parentela [5]) :

$$SRC=(w_1\frac{PER}{TLR}+w_2\frac{PT}{PTR}+w_3\frac{EQT}{ELR}+w_4\frac{PPE}{PPR}) \quad (2)$$

where:

SRC =	station response capability rating
PER =	personnel availability rating of a station
TLR =	team level requirement for a particular event
PT =	personnel training rating of a station
PTR =	personnel training requirement for a particular event
EQT =	equipment availability rating of a station
ELR =	equipment level requirement for a particular event
PPE =	personal protective equipment availability rating of a station

Terms w_1, w_2, w_3, and w_4 are importance weighting of personnel availability, personnel training, general control equipment, and personal protective equipment, respectively. A survey of fire chiefs representing Clark County, Nevada, U.S.A. and its cities resulted in the following average weights: w_1 = 0.19, w_2 = 0.28, w_3 = 0.29, and w_4 = 0.24. The weights indicate that the four criteria have more or less the same level of importance.

The severity of event and its level of hazard greatly influences the required level of response, and the size and make-up of the response team. According to severity, an event is categorized into minimal, moderate, and severe. Hazard level is defined by categories A to D. Level A represents the highest hazard, while Level D represents the lowest hazard. A 2-person team may be required for the least severe event with the lowest hazard whereas an 8-person team may be required for the most severe event with the highest hazard . The team member's ability to respond is measured by his/her level of training which could be (in an increasing degree of importance) at the awareness, operations, technician, and specialist level. Personal protective equipment is used to shield or isolate a person from chemical, physical, and thermal hazards. It ranges from Level A to D. Level A corresponds to the highest level of protection and level D, to the lowest level of protection. General control equipment includes first aid and other medical equipment, sampling equipment, emergency vehicles, and other tools required to contain the event.

A SRC greater than unity indicates better preparation than required, equal to unity indicates preparation equal to what is required, and less than unity indicates less preparation than required.

Transactions on Ecology and the Environment vol 24, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

3 Case study

A case study was performed to evaluate the emergency preparedness of Clark County, Nevada, U.S.A. Clark County is located southeast of Yucca Mountain , site of the proposed nuclear waste geologic repository. Figure 1 shows its location. Las Vegas, a rapidly growing community known for its tourist attractions, lies within Clark County. Currently, the State of Nevada is evaluating potential highway and rail routes that may be used for transporting radioactive materials to Yucca Mountain. For the highway mode, several alternate route options will allow materials to be transported from both the northern and southern parts of the states. These route options traverse segments of the major highway routes in Clark County, namely, I-15, US-95, and US-93 (see Figure 2).

Emergency preparedness along these major routes are evaluated for this study. The analysis involves identification of emergency response units, and their locations, determination of service zones, and evaluation of response capability. For purposes of the analysis, first response is assumed to be provided by the fire units. The locations of these units are shown in Figure 2. Two stations, designated as HAZMAT stations, are shown in Figure 3. These stations have manpower trained to specialist level, and equipment that could handle the level of response required by a HAZMAT event.

Response time is evaluated based on travel time only. Travel time is taken as the time to travel from the base location of an emergency response unit to the scene of an event. Travel speed of 80 kph was assigned on US primary roads and interstate highways, 72 kph on major arterial, and 48 kph on other roads. These were used to estimate travel times within the network. The speeds did not consider time of day which may have an impact on the analysis. Using the network analysis module of ARC/INFO, the network coverages of 5, 10, and 45 minute travel times have been evaluated as shown in Figure 4. Travel time distribution along the routes is shown in Figure 5. The percentage of routes that could be reached by a responder within 10-minute travel time is summarized in Table 1. About 50 percent of US-95 could be reached by a responder within 10 minutes. This percentage is much higher than those of I-15 and US-93 which have only about 25 percent of within the 10-minute travel time window. It is to be noted, however, that the areas outside the 10-minute response window have very low or no population as shown in Figure 6.

Transactions on Ecology and the Environment vol 24, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

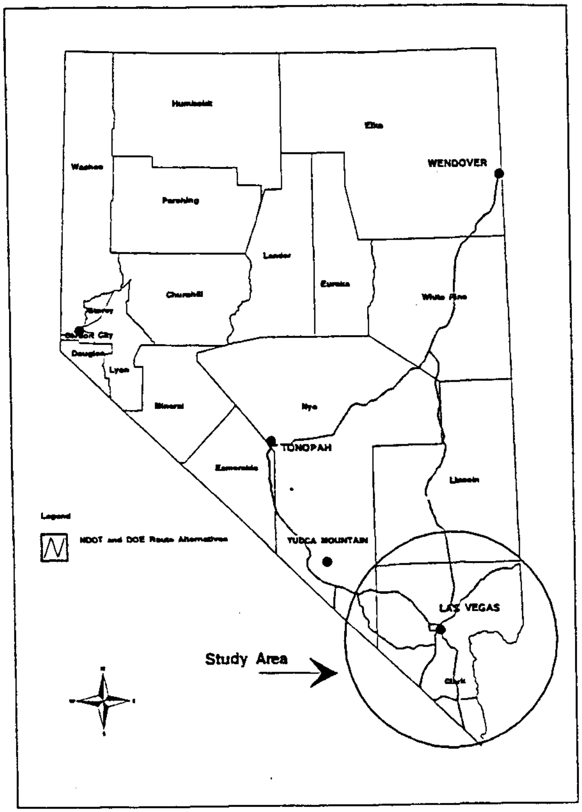

Figure 1: Case Study Area: Clark County, Nevada, U.S.A.

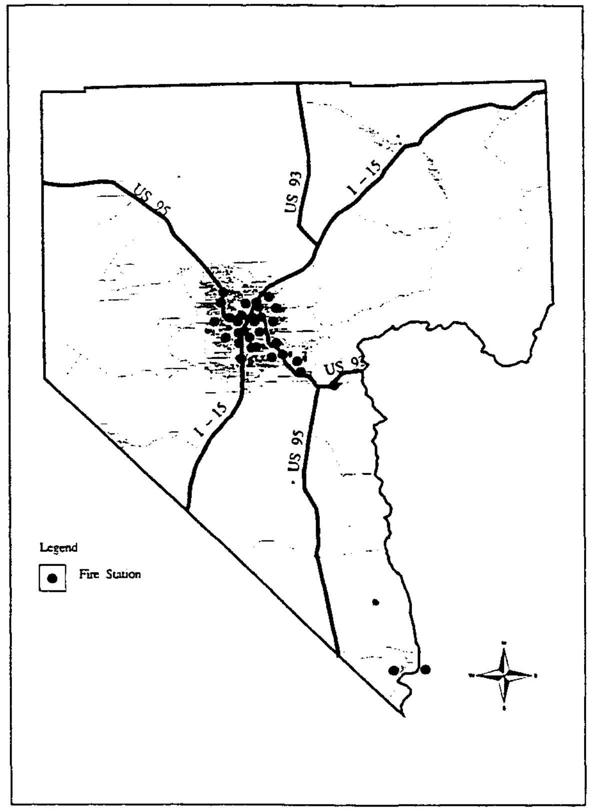

Figure 2: Potential HAZMAT Routes and Locations of Initial Responders

Transactions on Ecology and the Environment vol 24, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

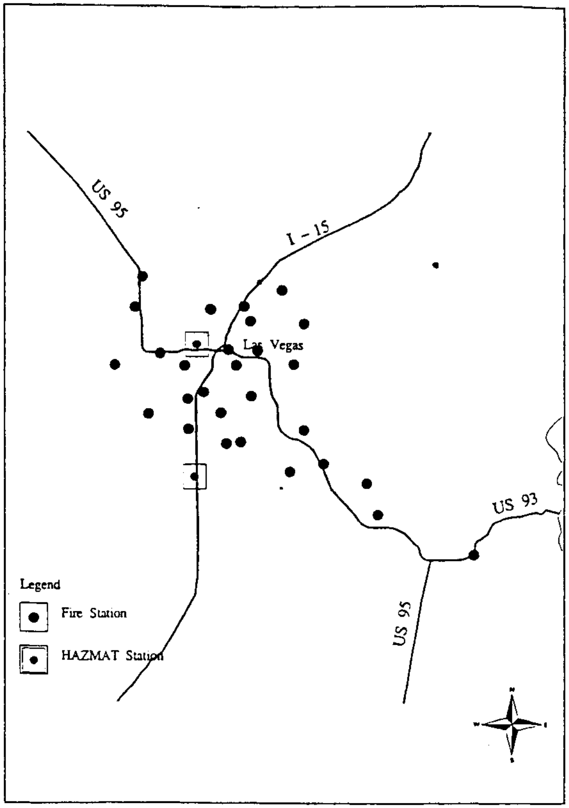

Figure 3: Clark County HAZMAT Response Teams

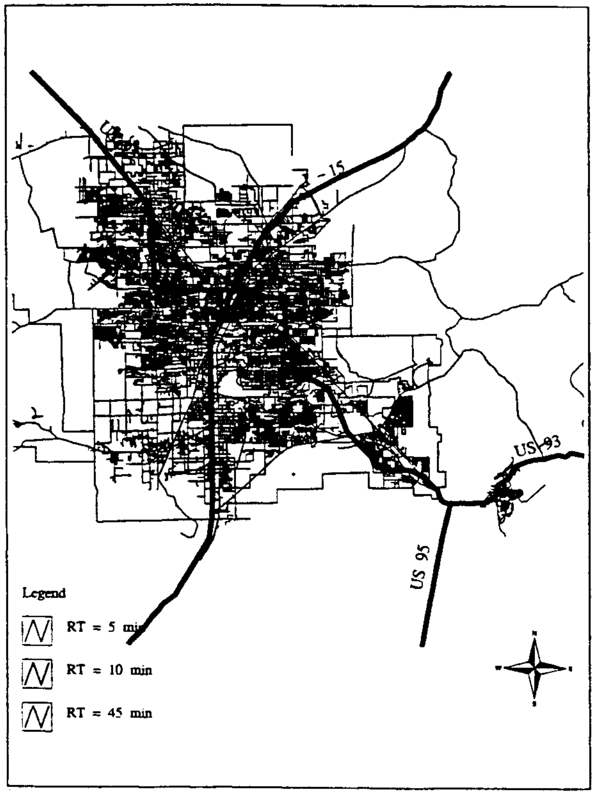

Figure 4: Network Allocation of Fire Units for 5, 10 and 45 Minutes Travel Time

Transactions on Ecology and the Environment vol 24, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

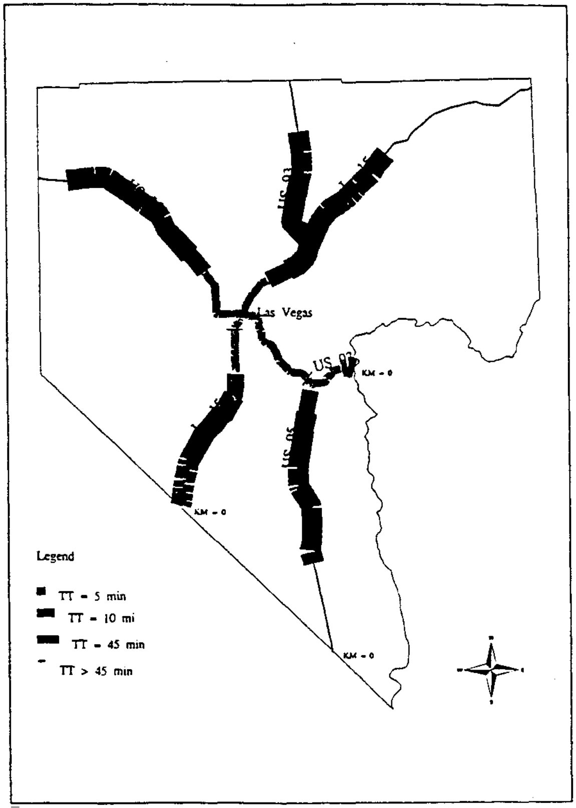

Figure 5: Route Segments with Travel Times of 5, 10, and 45 Minutes

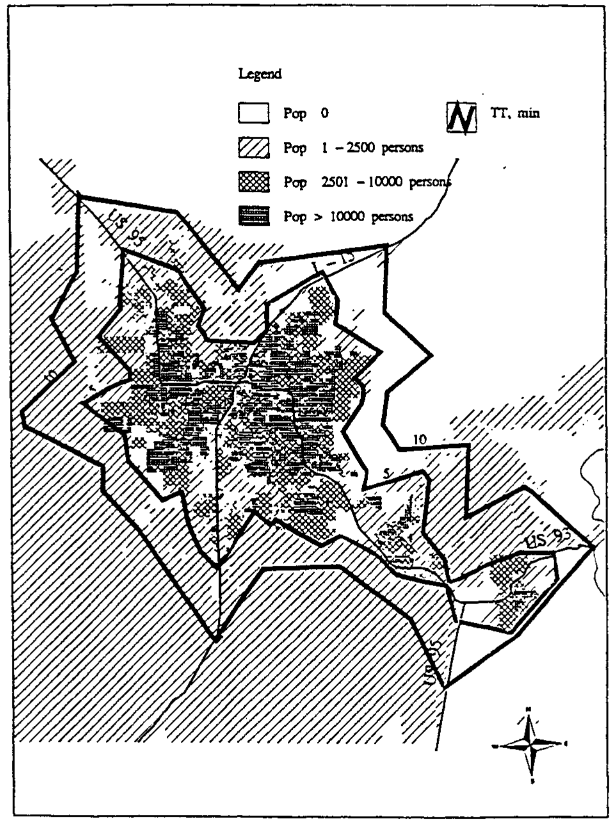

Figure 6: Travel Time Contours and Population Density Distribution in Clark County, Nevada

Table 1. Percentage Distribution of Routes for Various Travel Times

Route	US-93	US-95	I-15
Length, km	75.57	218.45	199.07
Percent of route within 10-min response	25.2	50.5	22.9
Percent of route outside 10 min response	74.8	49.5	75.1

The number of units arriving at the site with 10 minute are summarized in Table 2. As mentioned earlier, multiple units have the advantage of performing multiple tasks which could greatly minimize response operations and the consequence of an event. The result shows that the route segment of US-93 which could be reached within 10 minutes could be served by only one unit at a time. A significant portion of US-95 and I-15 could be reached by multiple units within 10 minutes.

Table 2. Percentage Distribution of Routes by Number of Response Units

Route	Percent of Route Covered by N Units (Within 10-Minute Travel Time)						
	N=1	N=2	N=3	N=4	N=5	N>5	Total
US-93	25.2	-	-	-	-	-	25.2
US-95	15.7	15.4	6.8	4.5	4.7	3.4	50.5
I-15	13.2	4.1	0.3	1.1	1.2	3.0	22.9

4 Conclusion

An evaluation of emergency preparedness is useful in assessing risk and community vulnerability in the event of an accident involving hazardous materials. Emergency preparedness is evaluated using various measures such as availability of response units, response time, and the capability of the response units.

The analysis enables identification of critical areas or those with very low emergency preparedness. Results of the analysis permit development of strategies for allocation of resources such as establishing locations for new response units, improving the capabilities of existing ones, and providing mobile stations at critical areas. Knowledge of the capability of the response units is useful not only for evaluating units requiring capability upgrade but more importantly, for identifying specialized units for deployment.

References

[1] Abkowitz, M.D., P. Alford, A. Boghani, J. Cashwell, E. Radwan, and P. Rothberg, State and Local Issues in Transportation of Hazardous Materials: Toward a National Strategy, *Transportation Research Record 1313*, TRB National Research Council, Washington, D.C., pp. 49-54, 1991.

[2] Rowe, W.D., Risk Assessment Process for Hazardous Materials Transportation, NCHRP Synthesis of Highway Practice 103, November 1983.

[3] Parentela, E.M., S. Burli, S. Sathisan and W.C. Vodrazka, Emergency Response Analysis for Radioactive Materials Routing, *Proc. of the 5th Annual International High Level Waste Management Conference and Exposition*, Las Vegas, Nevada, U.S.A., May 22-26, 1994.

[4] U.S. Department of Transportation, Federal Highway Administration, *Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials*, September 1994.

[5] Parentela, E.M., *A Framework for Modeling Risk and Emergency Response in Hazardous Materials Transportation*, Dissertation, University of Nevada, Las Vegas, 1996.