AN EXPERT SYSTEM FOR THE ON-SCENE MANAGEMENT OF HAZARDOUS MATERIALS INCIDENTS

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ABSTRACT

Every year a substantial amount of hazardous materials is transported internationally. The danger associated with accidental release of hazardous materials is substantial and sometimes catastrophic for the humans and the environment. The magnitude of the consequences of accidents involving hazardous materials shipments depends to a great extend on the effectiveness of the emergency response units dispatched at the scene of an incident.
The objective of this paper is to develop an expert system for the effective on-scene management of hazardous materials incidents. In particular, the developed KBES (Knowledge Based Expert System) aims to support the central dispatcher, who coordinates all the agencies involved in the incident management response, determine appropriate removal and clearance actions, dispatch and coordinate the required crew.

INTRODUCTION

The danger associated with accidental release of hazardous materials is substantial and sometimes catastrophic for the humans and the environment (Zografos and Davis, 1989). Therefore, concern about risks associated with hazmat has prompted development of incident management systems aiming to minimize the effects of an incident. An incident management system is the coordinated pre-planned or real time use of human, resources and equipment in order to reduce the duration and impact of incidents. Incident management systems, in general, exhibit differences in terms of their organization and structure but all share the following functional elements: a) Detection, b) Response and 3) On-scene management and clearance.

This research is focused on the third element of incident management because the on-scene management of hazardous materials accidents involves a wide spectrum of actions and complicated decisions where expert judgment is involved. The characteristics of the on-scene management problem suggest that the utilization of expert systems can enhance the quality of hazmat risk management decisions.

The objective of this paper is to describe the structure of an expert system for the effective on-scene management of hazardous materials incidents. The scope of the proposed KBES is to aid a central dispatcher in determining the appropriate removal or clearance actions, dispatch the pertinent equipment and coordinate the required private and public agencies. The agencies participating in the hazmat incident management actions are: a) the police department, b) fire department, c) traffic management center, d) medical centers, e) shipping companies, f) radio and television stations, and g) special incident management teams.

DESCRIPTION OF PROPOSED KNOWLEDGE BASED EXPERT SYSTEM

Managing hazamat incidents is a complex problem where different parties referred as stakeholders (Keeney, 1980) (i.e., government, shippers, emergency responders) are involved. Many tasks in the incident response procedure are so complex and ill-structured that conventional analytical tools are of limited use. Nevertheless, these tasks are addressed, and problems solved using human judgment and experience.

Expert systems are designed to emulate the performance of an expert or a group of experts in a particular problem domain and are primarily applicable to situations, like hazmat incident management, requiring specialized knowledge, skill, experience or judgment for determining a solution strategy. Many applications of expert systems on problems where human behavior, social and political considerations and decisions are involved can be found in literature (Yeah et al, 1986).

Transferring the expertise and knowledge from one or more experts to a computer program is the major task in building an expert system. The following steps give the outline of the expert system building procedure followed in this research (Roth et al, 1983):

Problem Identification.

The first step in building an expert system is to identify the area, concepts, and characteristics of the problem. In addition, the participants and their roles, goals, constraints and resources (time, labor, and computer facilities) needed or provided. In this step the involved agencies, in cooperation with the knowledge engineer, define the nature of the problem, the expectations that the system must fulfill and the skills of the KBES users (experts or non-experts). In the case of hazmat incident management 'central dispatcher'' evaluates the circumstances, at the accident site, determines the incident nature and appropriate response.

Knowledge acquisition

Knowledge acquisition is the most difficult stage in the KBES development process. In our case knowledge was acquired from various sources: a) Interviews with chemical engineers expert in packing and transporting hazmat, b) literature review in the area of hazmat transportation (US DOT, 1990), (CANUTEC, 1992), c) fire department, and d) private companies specialized in responding to incidents with great environmental impact (e.g., oil spills). The knowledge acquisition process revealed that the following steps are used when responding to hazmat incidents: 1) Incident detection 2) Incident verification 3) Transfer of information to central dispatcher\emergency response advisor, 4) Determination and application of the appropriate response scenario, and finally 6) monitoring and evaluation of incident condition.

Formalization and implementation

The proposed KBES simulates the central dispatcher who receives incident related information from a hazmat incident site. His\her first effort is to identify the type of spilled hazmat by: a) checking shipping documents (when possible) to determine the type of spilled material or at least identify the corresponding product identification number (PIN) and\or 2) the placard displayed on the ends and sides of a tank, vehicle, rail car, etc. If this information is not available then the shape of railcar or road trailer can provide useful hints for the type of spilled hazmat. The identification procedure is shown in Figure 1.

The next step in the incident management procedure is to determine more information about incident conditions, incident types, and severity e.g., fire, spill or leak existence etc. The dispatcher combines all the input information, evaluates the situation, matches the accident type with a similar one that exists in a library of events and determines the appropriate response actions, dispatches and coordinates appropriate agencies. This library of events, embedded in the proposed KBES, contains different types of events\incidents. The proposed KBES is an integration of various databases found in the literature and the heuristic knowledge and expertise obtained by interviewing experts. The algorithm used in the proposed KBES is known as " *describe -and-match* " algorithm (Vasilakis, 1994), (Winston, 1992). This algorithm has three steps:

- ⇒ Describe the incident and its nature using suitable representation and variables
- ⇒ Match the incident description against library descriptions until there is a satisfactory match or there no more other library descriptions
- ⇒ If you find satisfactory match announce it; otherwise announce failure

The steps involved in the implementation of the "describe and match algorithm" is shown in Figure 2. In particular, the central dispatcher transfers the information, reported by the crew at the incident site, to the KBES and the system attempts to match the reported event with the events stored in the library, selects the one that matches the existing situation, and selects the appropriate response.

The KBES requires a large number of variables, determined in real time by the central dispatcher, to operate. The system prompts the user to define the values of some variables, in order to identify the nature of the hazmat incident. For example the hazmat type, determined by the person reporting the incident at the incident site and the dispatcher (see Figure 3), environmental conditions (e.g., air, temperature, time of day), vehicle type, packaging type, injuries, specific information (e.g., fire, leak etc.) are the cornerstone for the KBES to operate properly. Obviously the system uses a large number of user defined variables and options which are not presented in this paper.

The KBES contains a library of almost 2500 hazmat. Materials that require similar treatment in case of an incident are grouped together and 52 groups were identified [6]. Therefore, 52 different response scenarios "guides" were constructed and the problem magnitude decreased significantly.

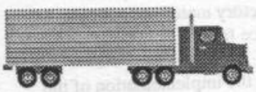
The structure of the proposed system is shown in figure 3. It details three data bases:

1) Database #1 that contains hazmat (almost 2500) classified according to their PIN number/of name and the corresponding "response guide". Example:
SHIPPING NAME: Sodium Peroxide *PIN:* UN1504
GUIDE: 28

2) Database #2 that contains CHARTS and LABELS of PLACARDS (25 totally) and corresponding response guide. Example:

corresponds to guide 018

3) Database #3 that contains different truck types (17 totally) and the corresponding response guide number. Example:



corresponds to guide 01

The first step of the proposed hazmat incident management system is to run the "guide # selection routine" shown in Figure 1 and extract from the aforementioned three data bases the appropriate guide number.

In the second step, the KBES is activated (Figure 3). Depending on the number of guide determined at the previous step the appropriate routine is activated (totally 52 routines are embedded in the KBES). For example if guide #18 is appropriate then routine # 18 is activated from the library of events and the user must define some variables to accommodate the proper operation of "describe-and-match" algorithm. The system then is able to state the appropriate recommendations in terms of potential hazards (fire\explosion and health), public safety (evacuation procedure, injury assistance if needed, etc.) and emergency response (fire extinguishing techniques, spill or leak removal, traffic detouring, etc.).

In more details, the proposed KBES provides information and recommendations about the protective clothing for the response team, evacuation, fire fighting, first aid and immediate medical assistance, and efficient management of an emergency. Factors considered for the evacuation procedure are: population at risk, hazmat quantities, hazmat properties, time of day, local weather and terrain conditions. In terms of fire fighting requirements the foam type is recommended.

<u>Test Example</u>

The following example is used to demonstrate the capabilities of the proposed KBES.

A truck transporting hazardous materials overturned. The truck driver is injured. The weather is rainy and a small fire and leak was reported. Time of day is afternoon and traffic near the incident site is light.

The KBES prompts the user to define the type of spilled material. The officer at the incident site reported PIN number UN 1504. The KBES scans the database and determines that the spilled material is Sodium Peroxide therefore, guide # 28 is applicable. Routine # 28 is activated and the user inputs the information. Finally the system comes out with the following suggestions; these suggestions concern the following areas:

Potential Hazards:

a) FIRE OR EXPLOSION
Attention the Sodium Peroxide reacts vigorously and\or explosively with water!!!
It produces poisonous and\or corrosive substances on contact with water
Runoff may create fire or explosion

b) HEALTH
Inhalation or contact with vapor, substance, or decomposition products may cause severe injury or death.
Fire was reported!!! Be careful fire will produce irritating, poisonous and\or corrosive gases and run-off from fire control or dilution water may pollute waterways.

Public Safety:

Leak was reported!!! Leak area should be isolated immediately for at least 50-100m in all directions. Keep upwind and out of low areas!!!

a) PROTECTIVE CLOTHING
Wear fully encapsulating, vapor-protective clothing!!!!

Structural firefighter's protective clothing is not effective

b) EVACUATION
The spill is small and no large containers are involved in the fire NO further evacuation is required.

Emergency Response:
a) FIRE
ATTENTION!!!! DO NOT USE WATER OR FOAM
The fire is small therefore use dry sand, dry chemical, soda ash or lime or withdraw from area and let fire burn.

b) LEAK
Eliminate all ignition sources (no smoking, flares, sparks or flame in immediate area).
Do not tough or walk through spilled material
Stop leak if without risk
The leak is small therefore cover with dry earth, sand followed with plastic sheet to minimize spreading and contact with rain.

First Aid:
A victim was reported at the incident site !!!
Remove victim to fresh air. Apply artificial respiration if victim is not breathing. CAUTION!!! do not use mouth-to-mouth methods if victim ingested or inhaled Sodium Peroxide; use the Holdger-Nielsen method (back pressure-armlift). If breathing is limited administer oxygen. Remove immediately contaminated clothing and shoes. Remove material from skin immediately. In case of contact flush skin with running water at least 15 minutes.

FOR THE DISPATCHER:

Call an AMBULANCE!!! But do not forget to inform the ambulance crew about the situation so they be prepared to handle the situation. Announce the situation to the public through radio and television, so people will avoid that area. Finally, organize traffic detouring process and dispatch appropriate police crew to realize your detouring scenario.

CONCLUDING REMARKS

An integrated KBES was developed as part of this research effort. The proposed KBES is not a substitute for emergency response training, experience and sound judgment but aims to facilitate the emergency response and prevent a catastrophe. It helps the emergency response dispatcher to determine appropriate response actions faster, easier, and the non-expert to behave like an expert and respond promptly and accurately. It is user friendly, providing explanation facilities on every level and from the programmer's point of view the system is transparent and modifications can be made easily and quickly. Finally, it manages a great amount of data and information faster and with greater accuracy than a human does.

Acknowledgments

This research was partially sponsored by the Hellenic General Secretariat for Research and Technology

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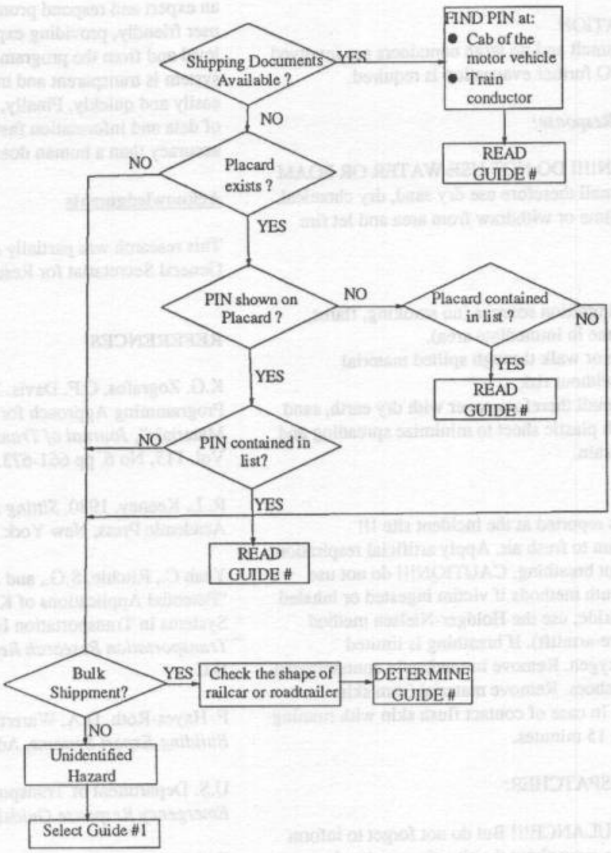

FIGURE 1: ROUTINE FOR "GUIDE #" SELECTION

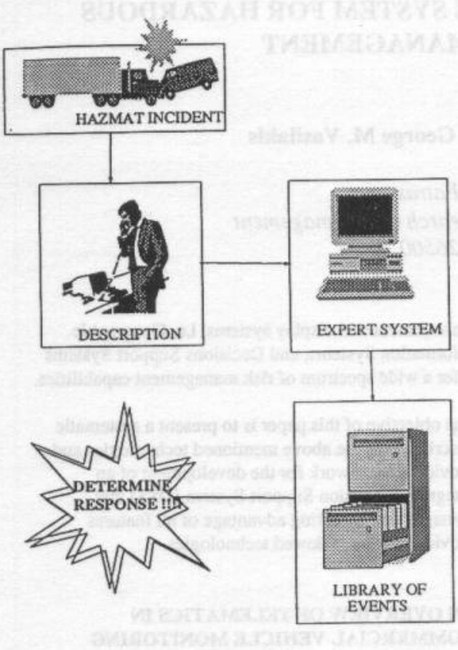

FIGURE 2: DESCRIBE-AND-MATCH ALGORITHM

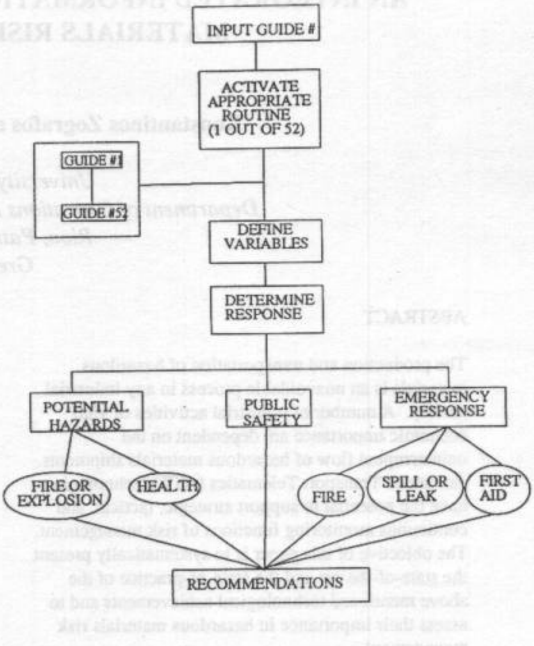

FIGURE 3: STRUCTURE OF THE PROPOSED KBES