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APPLYING GIS TO THE DELIVERY OF PUBLIC SAFETY WARNINGS

Abstract: In recent times, there have been numerous serious incidents in Australia involving emergency community evacuations following gas tanker explosions and toxic chemical spills and fires. In the aftermath of many of these events there has been strong criticism of the warning and evacuation procedures employed, which often took hours to perform as police labored to warn residents of the hazard by either door-knocking or using mobile loudhailers.

While emergency service agencies have developed efficient methods for delivering public safety warnings in the case of many natural hazards, their task is assisted by the fact that residents are usually aware that a hazardous event has occurred. However, in the case of highly-localised toxic material spills, affected communities often remain unaware of the threat. Consequently, in Australia at least, there is a growing call for new solutions to the problems of warning and evacuating communities in these situations.

The purpose of this paper is to propose a method for integrating GIS with new telecommunications technology to improve delivery of public safety warnings and to assist emergency service agencies to monitor the response and effectiveness of their warnings.

INTRODUCTION

> *"During the period 1981 to 1986, toxic gas releases accounted for approximately 150 deaths, 1500 injuries, and the evacuation of 220,000 residents in the United States".*
>
> (1, p. 846)

The moment of impact of a hazard initiates the emergency response period when saving lives and controlling property loss becomes a matter of minutes. Much of the effectiveness of the response by local residents depends upon the speed and effectiveness with which emergency services are planned, implemented and coordinated. In saving lives, prompt and efficient operations are critical. Basic problems in all emergency responses include obtaining accurate information on the nature and type of hazard, allocating and managing resources, and dealing with the movement of equipment and people in the affected area (2).

Of growing concern is the potential for damage which arises from hazardous material accidents as highlighted by Gould et al. in the quotation above. Indeed, the problem is occurring worldwide and in recent years there have been numerous serious incidents in Australia involving emergency evacuations of communities

following gas tank explosions and toxic chemical spills. In the post-hazard analysis of many of these events there has been strong media and community criticism of notification and evacuation procedures - which often took hours to perform as police labored to warn residents of the potential danger by either door-knocking or using loudhailers. On most occasions the results were less than successful since:

- elderly residents often refused to answer their doors at night,
- non-English speaking people had no idea what was happening;
- in some cases, there was little control over movement in and out of the area;
- entire streets were left unwarned because there was no method for monitoring which areas had been notified and which had not; and
- the police, who should have been coordinating the overall activity, were not able to do so as their resources were consumed in performing the evacuations.

While there have been attempts to reduce the incidence of potentially disastrous situations like these through the introduction of more stringent government controls (for instance with the transport and storage of toxic chemicals), the reality is that legislation can never provide the perfect solution to the problem and that some accidents will always occur. Accordingly, the point has now been reached where both government authorities and emergency service agencies believe that current emergency response procedures are less than adequate for the warning and evacuation process and that better solutions are required.

What is needed is the ability to quickly identify those sections of the community that need to be evacuated, notify them of the emergency at hand, and then detail the procedures they should follow. At the same time, emergency service authorities should be provided with the facility to monitor evacuation progress and therefore deal more effectively and efficiently with the situation at hand.

Already, there has been considerable application of GIS to some components of the emergency response problem. For instance, at the level of National/State/Province emergency management, Blower and Presley (3) discuss the requirements for an Alberta computer-based GIS to assist government management of hazards ranging from tornadoes and floods through to terrorist attacks, radiation leaks and even war. Similarly, Bacon (4) discusses the geoprocessing requirements for civil emergency management in New Zealand, while Barker (5) promotes the use of GIS as a means of providing Queensland's emergency managers with the necessary tools for contingency planning and response in the case of environmental accidents on coastal waters. In some cases, disasters have spurred the need for better information systems as Routh (6) noted after the 1989 San Francisco earthquake, in describing the emergency response management system being developed for the US Army Corps of Engineers.

At the technical level, Gould et al. (1) have developed a functional chemical emergency management system which incorporates spatial searching; an industry - related chemical database; and an air dispersion modeling package. McMaster (7) also uses software in applying a risk assessment model to determine community vulnerability to different hazardous situations. And at the operational level, Manuel (8) uses GIS in the Phoenix Fire Department for allocation of emergency services and more effective siting of facilities. Finally, GIS are not only being used reactively but also proactively, to ensure that land use is appropriate to a region given its susceptibility to natural hazards. Bender and Bello (9) cite applications of this approach in various South American Countries, while Hastie

(10) details a system used to model landslips in New Zealand.

However, while each of these works contributes to solving the overall problem of emergency management, until now the application of GIS for delivering public safety warnings has not been widely considered - even though it would seem to be a logical extension of the spatial searching and modeling applications already being developed.

Accordingly, the purpose of this paper is to examine the public safety warning process to determine how GIS may best be employed in these operations, and to propose a method for integrating GIS with new telecommunications technology which, when combined, has the potential to rapidly warn affected communities in times of danger.

THE PUBLIC SAFETY WARNING PROCESS

Before considering how GIS may be applied to delivering public safety warnings, it is necessary to examine the basic steps involved in the process (Figure 1). Firstly, when a hazardous situation occurs emergency service authorities must decide whether action is required. In some cases events such as floods, earthquakes and landslides occur in remote regions and only a monitoring watch is needed. However, most hazards pose either direct or indirect threats to both communities and the environment - hence the requirement for mitigating action.

At this stage, certain basic information is necessary for authorities to assess the level of threat posed by the hazard. This includes the location, magnitude and type of hazard; the level of resources available and required; weather, time and traffic considerations; the possibility of secondary hazards occurring (for example, fires after an explosion); and population distributions and characteristics in the affected zone. Of course there are many other factors that must be taken into account, but for the purposes of this paper these sample inputs are cited to demonstrate the basic information needed for assessment of the situation.

The action required can be categorised according to damage that either has already occurred or else may occur as a result of the hazard. For instance, action may be necessary to avoid economic damage to crops; sociological damage to members of the affected community; environmental damage in the case of oil spills; facility infrastructure damage; property damage caused by earthquakes; and of course threats to public safety which may cause injury or loss of life. Of these six categories, the latter shall now be considered in greater detail.

If there is a threat to public safety there are several considerations that need to be appraised before issuing a warning to the community. For instance, "Where is the affected area ?" is the most obvious question and relies upon reports of the nature, location and extent of the hazard. As previously mentioned, GIS are ideally suited to this modeling process and several applications have been cited in the references.

The next question is "Who is in the affected area ?" and here information concerning population distributions and priority sites, such as schools and hospitals, will be needed. "What form of message ?" must then be considered since there may be a high level of non-English speaking residents in the area and, in addition, a choice will need to be made as to whether residents should evacuate to a safer site or else stay in their homes/workplaces and take appropriate precautionary action instead.

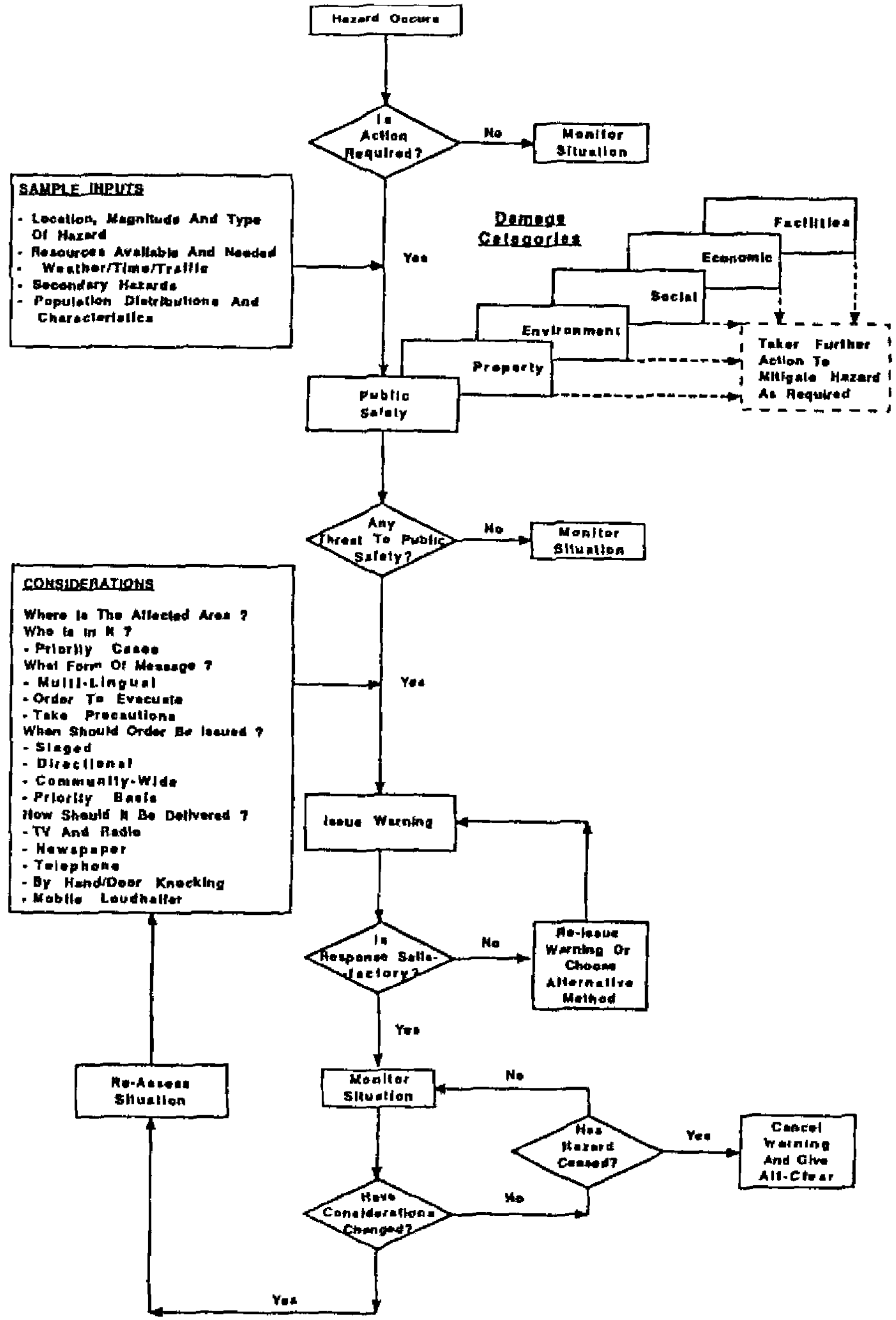

Figure 1: The Public Safety Warning Process

"When should the warning be issued ?" involves timing factors, which may lead to a staged warning being given to permit people closest the hazard to receive preference. On the other hand, threats such as toxic gas clouds may need to be accounted for with directional warnings, although some hazards are unpredictable and community-wide notice will be required.

Finally, "How should the warning be delivered ?" involves determining the most efficient means of message delivery which may vary from television, radio and newspaper through to telephone, mobile loudhailer or door knocking.

Having issued a warning, it then becomes vital to measure its effectiveness, with the consequence that the warning may have to be re-issued at periodic intervals or else an alternative method may need to be chosen. Once a satisfactory level of response is being achieved the situation can be monitored and re-assessed for changing conditions, if necessary. Finally, when the threat has ceased the warning can be cancelled.

This then, is a simple description of the public safety warning process, and the processes of integrating GIS and telecommunications technology to assist with the delivery of these warnings can now be discussed.

INTEGRATING GIS WITH TELECOMMUNICATION TECHNOLOGY

One possible technological solution to the delivery of public safety warnings is that of automatically telephoning affected residences and businesses. This could be highly resource-efficient and has the advantages that telephone messages might be less traumatic for residents (especially at night) and that the multi-lingual needs of non-English speaking citizens can be met.

A recent product that is helping to improve the delivery of community warnings is the QuickCall telephone notification system developed in the US - capable of simultaneously and automatically dialing around 1000 numbers in 15 minutes, although it can be expanded considerably past this dial-rate if required (11).

Recipients of the system are played a pre-recorded message which provides warning of the hazard and further instructions concerning the action to be taken. Already, one community in Oklahoma has purchased the system and leased it back to the local telephone company to provide early warning of tornados, at a cost to each resident of 95 cents per month.

An added advantage of the system is its ability to provide information regarding the level of response to the calls. As each recipient answers the call the system keeps a log of responses, and in the case of unanswered calls or engaged numbers repeat calls are made at pre-defined intervals.

However, while there is no doubt that this approach is effective in delivering community-wide emergency notification, it suffers from being relatively inflexible when required to deliver localised spatially-oriented warnings. For instance, it might be critical to identify all properties within a 500 metre radius of exploding LPG tanks or else a specific wind direction could be needed as input to determine who lies in the immediate path of a toxic gas cloud. Hence, it is this vital spatial component of public safety decision-making which is lacking in present telecommunication-based evacuation systems.

Clearly, if the two technologies of GIS and Automatic-Dialing systems can be successfully integrated, then emergency service agencies will possess a decision -making tool capable not only of identifying and automatically warning communities at risk, but also of graphically displaying public response to the emergency warning. In addition, such a system could hold pre-assigned priorities for each property so that institutions such as schools and hospitals would receive first warning - at the same time informing evacuation authorities of the possible need for extra resources to deal with these cases.

Figure 2 shows the components of the proposed GIS/Auto-Dial warning delivery system. At the initiation of the system following a hazard, the GIS is employed to determine community vulnerability and the properties affected by the threat. Basic data sets in the GIS would include parcel mapping; land use; ownership/occupier details; street addresses; property IDs; telephone numbers; and a pre-assigned warning priority attribute. Models such as those developed by McMaster (7) and Gould et al. (1) could be run externally by the GIS but essentially the end result remains the same - to determine which properties need be notified.

This dataset would then be sorted on a priority basis and the telephone numbers for the selected properties extracted as a single data file - which then serves as the input to the automatic-dialing system. Because only text data are being transmitted between the GIS and the automatic-dialing system, the two systems can be connected remotely using standard telecommunication services. Indeed, the location of the automatic-dialing system is immaterial in a technical sense, although from a cost viewpoint the warning calls would probably be made from a system as close as possible to the threatened community.

As responses to the calls are recorded, they are sent back to the GIS where re-matching telephone numbers with property IDs enables responses to be mapped. Finally, there are various forms of presentation graphics available, ranging from initial land use and affected property maps and listings of priority sites, through to progressive output of response maps and tabular listings of properties unable to be contacted and which need to be followed up by other means.

FUTURE RESEARCH

At the time of writing, the preliminary model described in Figure 2 is being reviewed by several Victorian emergency service agencies to gain the input necessary for its practical refinement. The next phase of the research will be to apply and test the model in a GIS environment. One test area will be the Melbourne Knowledge Precinct (a heavily developed inner-city site) for which a GIS already exists (12).

This system already holds property mapping for 2600 land parcels and includes attribute data such as street addresses, ownership and tenant information, land use descriptions, property values, building types, and planning zones. All that is needed is the addition of telephone numbers for each property, and while random-generated values will be used for model testing, the author has spent the past two years adapting Telecom Australia's customer databases for GIS usage - with the result that many of the practical problems to be expected in implementing this aspect of the system have already been encountered and overcome.

In addition, because a single test site may be insufficient to fully prove the system, other data sets will be sought to test the influence of varying distributions of land

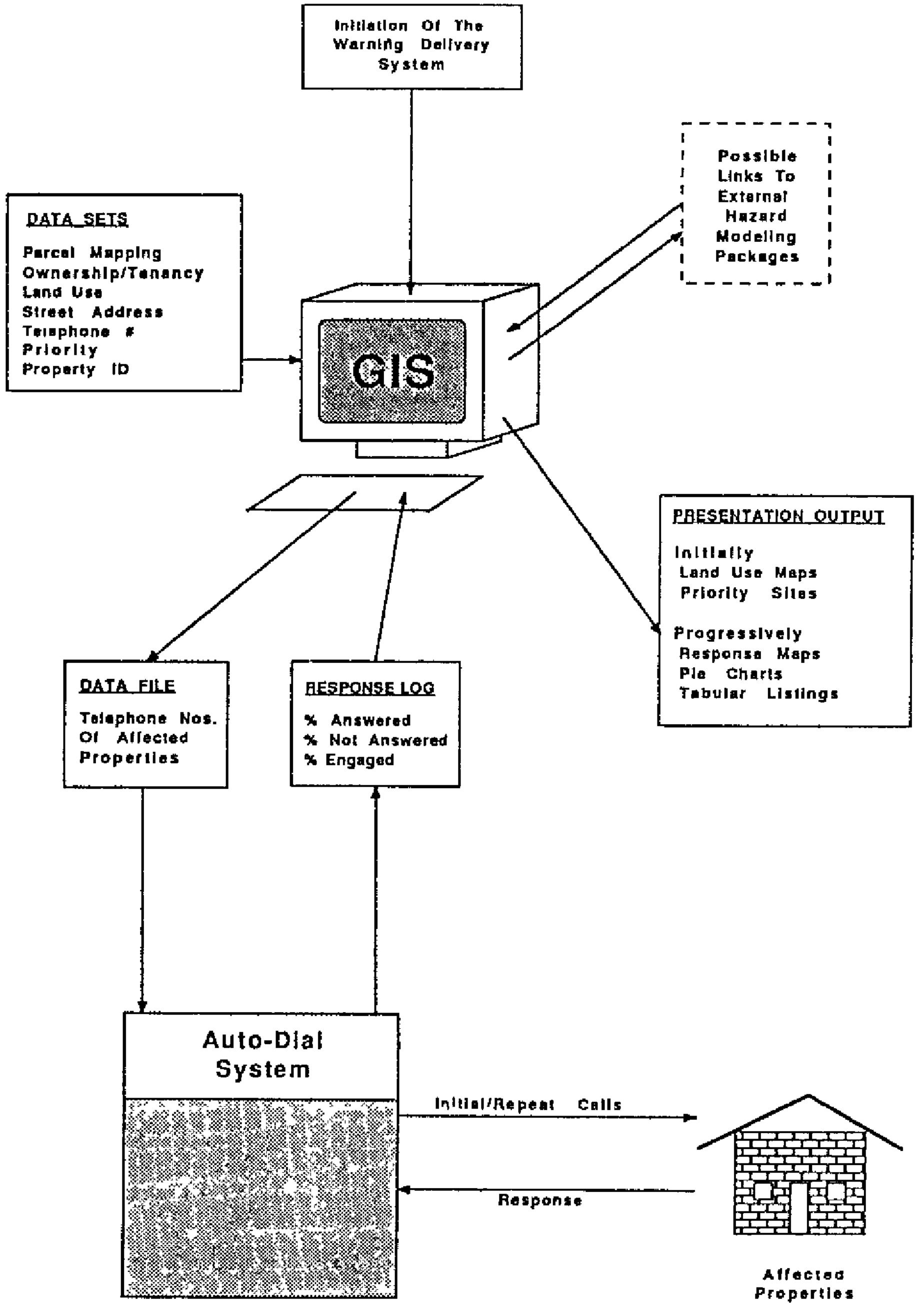

Figure 2: The Proposed GIS/Auto-Dial Warning Delivery System

usage patterns, land parcellation and telephone utilisation. The real-life problems of implementing such a system will also be investigated. These include determining the optimum scale at which such a system should be introduced (that is, statewide, regional or local); methods for updating telephone number/property associations; interfacing GIS with auto-dial systems; and examining how emergency service authorities can most effectively interact with the system.

CONCLUSIONS

In notifying and evacuating communities threatened by hazardous situations, emergency managers need the ability to quickly and efficiently identify those sections of the community that need to be warned, notify them of the emergency at hand and then detail the procedures they should follow. At the same time, emergency service authorities should be provided with the facility to monitor evacuation progress and therefore deal more effectively with the situation at hand.

While there has already been considerable application of GIS to some of the operational and technical components of the emergency response problem, until now the application of GIS for delivering public safety warnings has not been widely considered - even though it would seem to be a logical extension of the spatial searching and modeling packages already being developed.

The purpose of this paper has been to examine the public safety warning process to determine how GIS may best be employed in these operations, and to propose a method for integrating GIS with new telecommunications technology which, when combined, has the potential to rapidly warn affected communities in times of danger.

REFERENCES

(1) Gould, M.D., Tatham, J.A. and Savitsky, B. "Applying Spatial Search Techniques to Chemical Emergency Management" in Proc. GIS/LIS '88 Conference, San Antonio, Texas, Vol. 2, pp. 843-51 (1988).

(2) U.S. National Research Council. Reducing Disaster's Toll: The United States Decade for Natural Disaster Reduction (National Academy Press: Washington, DC) 1989.

(3) Blower, L. and Presley, H. "Province-wide Emergency Response Computer System" in Proc. 27th URISA Conference, Edmonton, Canada, Vol. 1, pp. 84-95 (1990).

(4) Bacon, C.J. "Geoprocessing Requirements for Civil Defence Computing in New Zealand" in Proc. 17th Annual Conference of the Australasian Urban and Regional Information Systems Association, Perth, Western Australia, pp. 299-307 (1989).

(5) Barker, T. "A Response Information System for Chemical Spills (RISC) in Moreton Bay" in Proc. 18th Annual Conference of the Australasian Urban and Regional Information Systems Association, Canberra, Australian Capital Territory, pp. 105-14 (1990).

(6) Routh, K. "Loma Prieta, California Earthquake, 1989 Spurs Development of a GIS-Based Emergency Response System" in Proc. 27th URISA Conference,