COMPARISION OF GIS-BASED PUBLIC SAFETY SYSTEMS FOR EMERGENCY MANAGEMENT

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ABSTRACT

Disaster and emergency response and recovery efforts require timely interaction and coordination of public emergency services in order to save lives and property. Today computer-based application guidance systems, also called Public Safety Systems, are used for the coverage of emergencies. In this paper we sketch the structure and functions of these systems and describe which roll Geographic Information Systems play in Public Safety Systems. The results of the study are the basis for further work in the field of emergency management.

1. INTRODUCTION

The key in saving lives and properties in emergency cases is to start the emergency aid operations as soon as possible. These activities are organised by the emergency centres, such as for example Red Cross or fire brigades. In these emergency centres, computer-based application guidance systems (Public Safety Systems) are used to coordinate the emergency aid activities, rescue teams and administrations. Most of the data, required by such applications is of spatial nature and can be located and visualised with the help of maps. According to these intentions spatial information is needed, and Geographic Information Systems (GIS) are well adapted tools providing required functions and data sets.
The goal of our comparison study is to show which roll a GIS plays in Public Safety Systems (PSS). Examples of GIS based PSS which are based solely on raster data can be found in Kippenberg (*1998*). As a result of the rapid development of GIS in the last years, the GIS functions included in PSS are now based on a combination of raster and vector data. A number of Public Safety Systems exist and we studied five commercially available and successful applications.
The structure of this paper is as follows: After this introduction we start with the explanation of the disaster management activities and the structure and functions of PSS. In section 3 we evaluate PSS regarding to the interface, geodata and GIS functions. In chapter 4 we make a summary of the comparison study and finally we will conclude the paper with some directions for further research work on this topic.

2. PUBLIC SAFETY SYSTEMS AND DISASTER MANAGEMENT

2.1. What is Disaster Management?

Disaster is a broad term which can include rapid-onset natural and man-made hazards containing avalanches and railway accidents, slower creeping crisis such as drought, famine or disease and disaster events that have a different time lapse like floodings or hazardous incidents in nuclear power plants (*Zerger, 2003*). It is difficult to define a disaster because it has varying magnitudes, temporal and spatial dimensions and varying social and economic consequences. The impacts of disasters change the socio-economic environments of our life locally, in many cases regionally. For the purpose of this paper, disasters can be defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (*ISDR, 2004*).

The total systematic coordination activities for the prevention and respectively the coverage of natural and man-made disasters are termed as disaster management activities. These activities can be grouped into five phases as suggested by Plate (*2001*) and ESRI (*1999*). They are structured by time and function for all types of disasters (see Fig. 1). These phases are related to each other and they involve different types of skills.

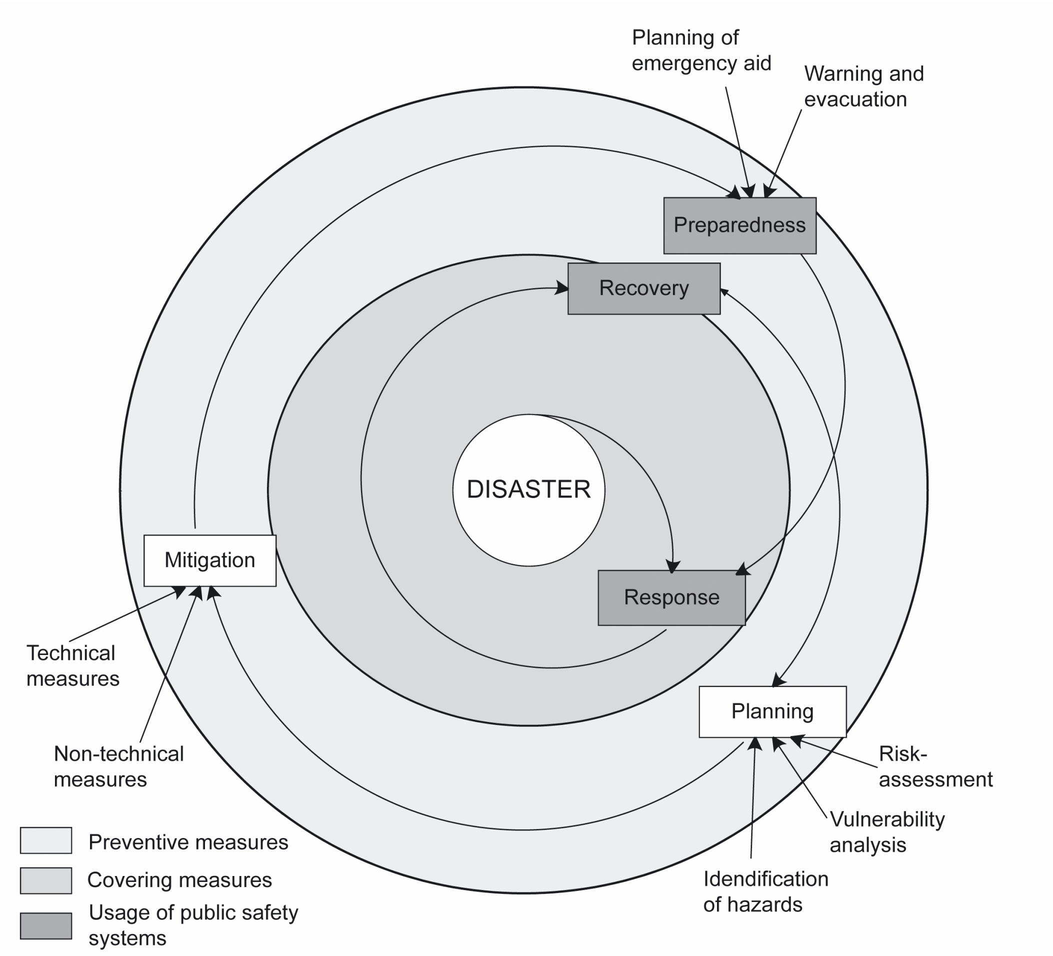

Fig. 1: The Cycle of Disaster Management (Leitinger, 2002)

The preventive measures are divided into planning, mitigation and preparedness activities. During the **planning** phase it is necessary to analyze and document the possibility of an emergency event or a disaster and the potential consequences or impacts on life, property and environment. The results of this phase are essential for the next preventive phases. **Mitigation** activities eliminate or reduce the probability of a disaster. It includes long-term activities designed to reduce the effects of unavoidable disasters. In the **preparedness** phase governments, organizations and individuals, develop plans to save lives and minimize disaster damage. Preparedness measures seek to enhance disaster response operations. When a disaster or emergency happens, the **response** activities are designed to provide emergency assistance for victims. They also aim to stabilize the situation and reduce the probability of secondary damage and speed recovery actions. The **recovery** activities aim to return the living conditions to normal or better and they usually include two sets of activities. Short-term recovery activities return vital life-support systems to a minimum operating standard. Long-term recovery activities may continue for a number of years after a disaster. This phase represents also the first step to a new planning phase, because this is the point when the analysis of the cause of the disaster or emergency takes place.
Public Safety Systems (PSS) are used in three phases within the disaster management. During the preparedness phase governments and organizations provide personal training in how to use the PSS. The main application of these systems is in the response phase, where computer programs give instructions to the rescue teams. In the case of the emergency situation, the emergency call will be accepted and the rescue teams alarmed and controlled. In the recovery phase PSS produce maps showing the extent of the damage caused by the disaster.

2.2. Structure and Function of Public Safety Systems

Basically, Public Safety Systems have modular components. The basic module is designed to support the decision-making and to handle the emergency. All additional modules enable the emergency aid and management of the rescue teams. This design allows several public safety organisations (Red Cross, fire brigade, police) and other organisations (automobile associations, energy supply companies) to customise the PSS for their different needs. In this paper we will review PSS developed for fire brigades and ambulances. The structure and function of PSS is shown in Fig.2. This is also the minimum requirement of PSS:
If an emergency happens (car accident, fire in a flat, etc.) somebody will transmit an emergency call to the centre of the rescue team. There the scheduler acquires the incoming emergency call with the necessary criteria including location, time, type, persons which are involved, etc. in the emergency. This information is the solicited input for the decision support module of the PSS. The next step is the disposition of the emergency forces. The PSS will submit, on the basis of the acquired information, the available resources and the alarm plans to the necessary emergency units. The scheduler controls the automatic proposition of the system and alerts the emergency forces. Simultaneous to the alarm important information (location, type, route to the location) will be sent to the alarmed rescue teams. During the emergency mission the emergency units are controlled and additional information which is needed to handle the emergency can be requested from the emergency call centre (e.g. queries form hazardous material databases). All steps, from the time of the emergency call to the status of the emergency forces like the location of the vehicles or the used equipments to the end of the emergency mission, are logged by the PSS to a protocol. In the post-processing phase all missing data of the emergency will be completed and a report of the emergency mission is generated and saved in a database.

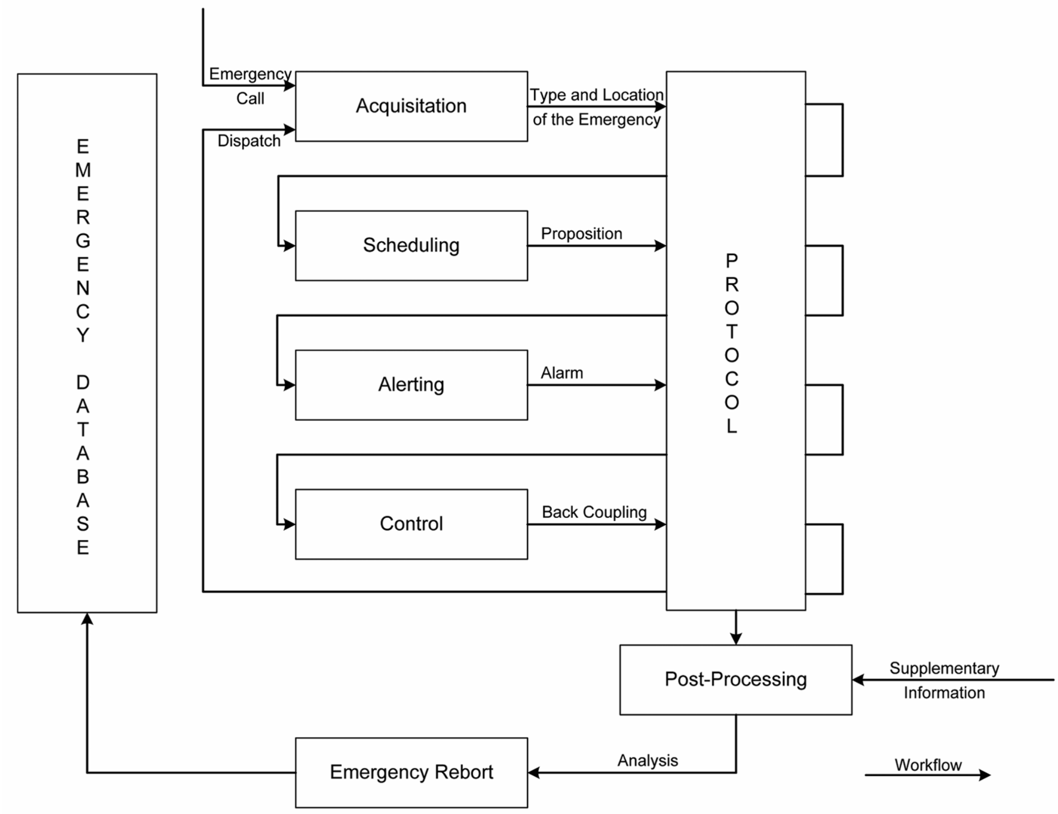

Fig. 2: Structure and Function of Public Safety Systems (Leitinger, 2002)

Other important modules of PSS are external applications which allow an unobstructed emergency handling. These programs are directly integrated to PSS and queries can be taken from several databases as hazardous material databases, electronical telephone books or other relevant emergency databases. Many PSS have also integrated alarm plans of high risks infrastructures e.g. schools, hotels, hospitals, trade and industry buildings. These alarm plans contain important information such as facility information, location of hazardous materials, escape routes etc., for the emergency units. Additionally other modules are included in a PSS, for example tools for the administration of personal and storage and for the calculation of the costs of an emergency mission.

3. EVALUATION OF GIS-BASED PUBLIC SAFETY SYSTEMS

For the goals of our study we selected the following five, commercially available Public Safety Systems: CKS-112 developed by CKS Systeme, ELDIS 2 developed by Eurofunk Kappacher, I/CAD developed by Intergraph Public Safety, ELS/GEOFIS 3.0 developed by Novotec Engineering and secure.Control developed by Wesser Informatik. These five applications can be considered as the international market leaders in this area. We compared interfaces between PSS and GIS, used geodata and basic GIS-functions which are integrated in these systems. The results of the comparison of the five PPS are presented in chapter 4 in Table 1.

3.1. Interfaces between PSS and GIS

The solutions differ substantially according to the interface between PSS and GIS, which is realized in three different types. In the first case (Fig. 3a), the PSS and GIS are considered to be independent, stand-alone tools and connected to each other through the exchange of the data (import/export of data). This PSS application can work without a GIS. The GIS-modules can be loaded individually to the system. In the second case, GIS is an integrated part of the PSS. Within this application form the user is able to run basic GIS functions. In the third solution, the PSS is an integral part of the GIS. Here the basic application is a GIS program and the PSS-modules are developed in addition to the GIS functionality.

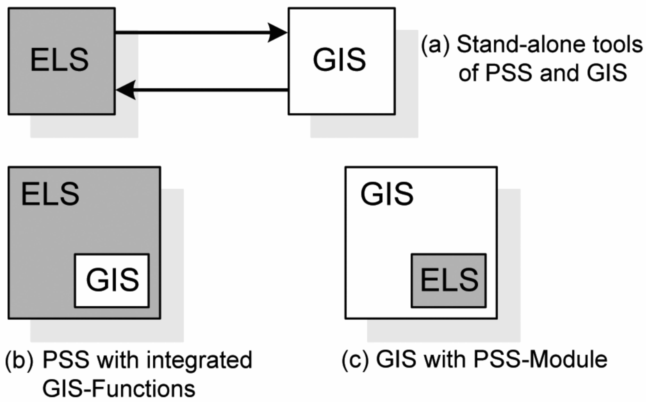

Fig. 3: Architecture of GIS-based Public Safety Systems

3.2. Geodata in Public Safety Systems

All compared PSS use similar structures of geodata. As in many GIS applications, the geodata differ between grid and vector data. The **grid data** in the form of digital topographic maps and remote sensing data serve for a better overview of the emergency situation. Depending on the emergency site (urban or rural regions) different maps, like city or regional maps, aerial photos and satellite images are used to visualize the emergency location. For viewing this maps and images standard-tools for clipping, panning and zooming are integrated into PSS application.
The GIS analysis in PSS is based on a **vector dataset** which includes beside other data also geocoded addresses and the street network. Operation areas of the public safety organisations, water bodies and lines and point of interest (POI) like locations of rescue teams, SOS-telephones and hydrants are used for the cartographic visualisation of the emergency area. In any case it is important that for a successful emergency aid all data is up to date (*Hanke, 2002*).

3.3. GIS Functions in Public Safety Systems

The main GIS functionality of PSS is a function that uses **geocoded addresses**. This function is required in order to enable localization of the emergency site. The addresses are usually organised in a dataset, which include the necessary geographic information, e.g. coordinates. In addition to this function, the emergency location can be entered via the street name or ordinary geographical coordinates.

The second important GIS function is the **network analysis**. In the network analysis the shortest or the fastest way between the position of the emergency forces and the emergency site is calculated. This function uses miscellaneous parameters, such as one-way-streets and turn restrictions. Applications designed for ambulances use the function of the "travelling salesman problem" for calculating the cheapest way between the location of the patients and the health care centres (hospitals, foster homes, medical specialists). The acquired routes are then shown on the cartographic visualisation tool and sent as GPS-coordinates or as a textual list of directions to the emergency vehicles.

The **cartographic visualisation** of emergency sites is another important function of PSS. It is usually presented on a digital map which can be completed with tactical symbols, simple drawings and labels. With the help of GPS transmitters the current position of the vehicles is acquired and visualised with symbols on the map. In additional layers, buildings with high exposure, like hospitals, schools, hotels, etc. can be displayed on the map or retrieved from special building databases. Other GIS functions included in the graphic display of PSS are the measurement of routes and surfaces and the query of specific emergency data.

Additionally to the described GIS functions, some PSS applications enable also a simulation of atmospheric **dispersion of hazardous materials**. The dispersion models are standard calculation models with experience values. The result of the dispersions model (a polygon) is combined with other geodata, like geocoded addresses to warn the affected population.

4. SUMMARY OF THE COMPARISON STUDY

Since the study of *Kippenberg* (*1998, pp. 37*) was published, the GIS-based public safety systems changed considerably. In his study, the basic data sets of PSS consist of raster data, where the storage of attribute data of emergency information is very difficult. The emergency location is defined by street names, which are identified by the partial vectorisation.

Criteria for Evaluation	**Public Safety Systems**				
	CKS-112	**ELDIS 2**	**I/CAD**	**ELS/ GEOFIS**	**secur. control**
Architecture GIS – PSS					
stand-alone modules of GIS and PSS	•				
PSS with GIS modul		•	•	•	
GIS with PSS					•
Geocoded Adresses	•	•	•	•	•
Network analysis					
optimum way	•	•	•	•	•
Travelling Salesman Problem (TSP)	•				
cartographic visualisation	•	•	•	•	•
simple standard functions	•		•	•	•
query of emergency data	•	•	•	•	•
integrated alarm plans of high risks facilities	•	•	•	•	•
simulation of atmospheric dispersion of hazardous materials	•				•

Tab.1: Summary of the comparison study of GIS-based public safety systems

Current, commercially available PSS applications enable address queries and include also vector based data. The street network data are usually stored in a vector format which makes the function of the network analysis possible. Raster data sets are only used for the cartographic visualisation of the emergency location.
The results of the study are shown in Tab.1. The architecture of most systems is a PSS with a GIS-module. In one product the GIS is the basis and the PSS is developed as an additional functionality in GIS. On the other hand, in one PSS application GIS functions can be loaded additionally to the PSS functions. Standard GIS functions, such as for example query of geocoded addresses and the network analysis are included in all analysed PSS applications. The function of the travelling salesman problem (TSP), usually used for the ambulance car, is applied only in one application. The modules for the graphical emergency aid, the query of additional emergency data and standard functions for the graphical interface are nearly integrated in all systems. The integration and visualisation of special facility plans into PSS was not possible in 1998. In the meantime, this specification is implemented in all analysed PSS products. An additional GIS function, which is implemented in two products, is the dispersion modelling of hazardous materials. However, the models are on the basis of simple mathematical functions and do not regard scientific dispersion models.

5. CONCLUSIONS AND FURTHER WORK

The comparison study gave us an overview of the currently used Public Safety Systems. They can be used for emergency cases e.g. traffic accidents or small fires where the emergency teams need GIS functions to query addresses, to find the way and to map the emergency location. We compared the interface between PSS and GIS, the geodata used in such applications and the basic GIS functions.
The disadvantage of the compared PSS systems is that they do not use real-time traffic data such as information about the current traffic flow and traffic jams for the network analysis. They are also only partially usable for large emergencies or disasters because the covering activities of these unusual events need systems which can be used directly at the emergency locations. For these requirements it is necessary to develop mobile applications.
In the future we would like to deal with research activities regarding to the interoperability of data of different emergency organisations, the possibilities of mobile applications for the emergency management and the usability of mobile applications as seen from the user's point of view.

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