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APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS FOR A CITY EMERGENCY MANAGEMENT

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Abstract: This paper presents basic information about GIS and reveals process of creating system application for a city emergency purposes. Traditional and modified rescue processing schemes are presented and compared. As a result a model of optimal Integratred Emergency Management System is described and tested by a trial software implementation based on Gdansk area data.

1. Introduction

There are many examples of GIS' application for urban needs. Many commercial products exist on the market using GIS technique, for instance FEMIS (Federal Management Information System), E-911 or Dispatch 911. But in spite of this creating a universal system which will work properly in almost every condition is necessary.

In Poland many cities are working on creating their own Integrated Emergency System. According to the law from 11th July 1992 issued by the Ministry of Internal Affairs, National Fire Brigade — PSP (Państwowa Straż Pożarna) is responsible for co-ordinating rescue actions within a city. An Integrated Emergency System is created for National Fire Brigade needs. It is a decision support system that integrates all phases of emergency management. Creation of such a system requires close co-operation among many different services. In Gdansk there are 14 services as following:

1. Fire Brigade
2. Emergency Policy Squad
3. Medical Emergency Service
4. Gas Emergency Squad
5. Energetic Emergency Squad
6. Emergency Crane Squad
7. Emergency Sewage Squad
8. Administration of Housing Estate
9. Forest Administration

10. Railway Administration
11. Individual Company Administration
12. Administrative Board
13. Autonomy Administrative Board.

2. Emergency Management System

Nowadays in Gdansk in case of an emergency event it is difficult to decide which emergency number (there is a list of classified emergency telephone numbers depending on event) should be chosen (Figure 1). Such kind of the emergency system is not effective. All around the world emergency system reaction is based on one global telephone number. It is obvious that only one emergency centre exists and even if there are several numbers, one always gets connected with the main operator (Figure 2). A person who calls gives exact description of the situation happened and on this ground the operator of an emergency system will make a decision what kind of specialised services will be necessary during the emergency action. Rescue teams allotted to participate in the action are informed at the same time and also at the same time they arrive at the emergency place and begin their work. It is an effective activity in all phases of emergency action.

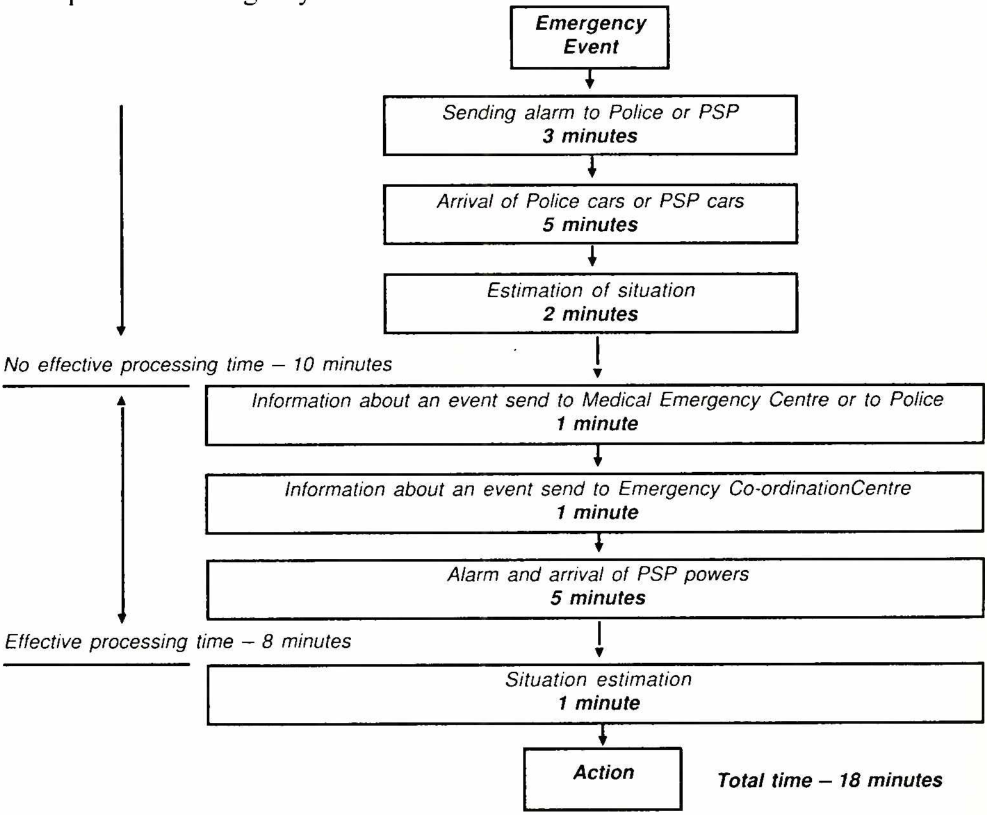

Figure 1. *Time scheme of traditional rescue processing*

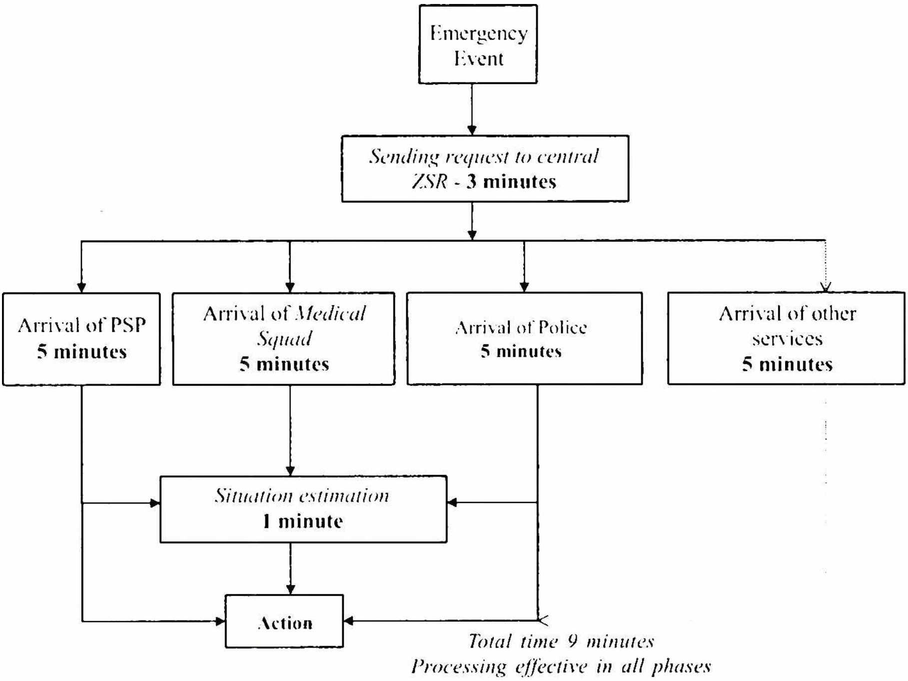

Figure 2. *Time scheme of proper working emergency system*

Geographic Information System for a city emergency should provide the planner with integrated tools to:

1. generate and distribute emergency plans, track resources,
2. collect and use real time data from weather monitors,
3. generate event logs and status boards,
4. display the location of real or potential hazard events via a geographic information system,
5. model and display plumes of hazardous material releases,
6. animate plume movement over time,
7. determine and display areas of risk,
8. automate the formulation of protective action recommendations and decisions,
9. generate and display evacuation routes,
10. simulate anticipated traffic conditions during emergency evacuation.

Menaces within a city

City menaces can be divided into two main groups:

1. industrial catastrophes,
2. municipal catastrophes.

An industrial catastrophe can be defined as a catastrophe which takes place in a factory area: for instance a fire of factory buildings or improperly stored inflammable materials, leak of toxic substances which could result in local soil contamination, inflammable materials explosion which could result in air and soil contamination, etc.

A municipal catastrophe is a catastrophe, which happens within a terrain with buildings where endangered people live. The following accidents are classified among municipal catastrophes:

1. fire (for instance caused by improper storage of inflammable materials in a house cellar or of forest terrain, specially in a summer season),
2. car crashes,
3. tanker crashes,
4. sewage catastrophes,
5. explosions, e.g., explosions of gas installations,
6. alarms about putting bombs,
7. small operations of human life rescue,
8. small operations of animal life rescue,
9. liquidation of hurricane or flood results,
10. liquidation of leak or local contamination results.

The main advantages of creating an Integrated Emergency Management System (IEMS) for a city needs are the following:

1. allows to forecast some catastrophes,
2. reduces losses and potential menaces,
3. speeds response of emergency services,
4. reduces a contamination risk by beginning the rescue action quickly,
5. gives immediate solutions about evacuation routes, which allows to save human lives.

To achieve those goals we created a project of IEMS with a pilot implementation using ArcInfo and ArcView software.

3. Project design

A structured methodology of system construction during system analysis and design has been chosen. In this methodology the process of building the system does not pay attention to system implementation details such as methods of data storage or others. Complex problems and functions are divided into smaller parts. Using this approach a system designer makes more detailed diagrams and makes reorganisations of logical system model according to the requirements and system limits. Next, there is a possibility of a new physical system definition taking into consideration implementation limits. Created models are transformed into a real system.

Integrated Emergency Management System is a system which needs a lot of different types of data to satisfy the system operator. The first step in the project design is creation of data dictionary which includes description of all data types useful for IEMS (Table 1).

Table 1. *Data dictionary of IEMS.*

Name of entity	*Type*	*Name of entity*	*Type*
building	spatial	street name	no spatial
building entrance	spatial	type of street	no spatial
building picture	spatial	rail axes	spatial
building plan	spatial	rail sections	spatial
type of building	no spatial	railway station	spatial
street axes	spatial	owner	no spatial
streets polygon	spatial	water bodies	spatial
street sections	spatial	fire departments	spatial
fire departments	spatial	green area	spatial
hospital	spatial	school buildings	spatial
medical assistance	spatial	school entrance	spatial
police	spatial	nursery buildings	spatial
specialised service departments	spatial	nursery entrance	spatial
public telephones	spatial	industry	spatial
specialised equipment	no spatial	hazardous materials mapping	spatial
vehicle	no spatial	gas system	spatial
type of vehicle	no spatial	water supply infrastructure	spatial
chemistry	no spatial	electricity supply infrastructure	spatial

The IEMS will also operate with external databases as following:

1. External Database of TSP (toxic substances database),
2. External Vehicle Database,
3. External Meteo Data (which is used to calculate a radius of first and second contamination plume),
4. End user,
5. External Database of Specialised Equipment.

Design of the IEMS functions is the next very important stage in the system design. Functions which will be implemented in the system are described in Table 2.

Table 2. Functions implemented in the system

Name of function	*Short description*
Location of municipal catastrophe	1. Search the place of emergency 2. Visualise it at the digital map 3. Give data about the found place 4. Display picture of the place (if any) 5. Display plan of the place (if any) 6. Show needed emergency squads
Searching the shortest path	Look for the shortest path for vehicles taking part in rescue operation
Localisation of hazardous area	Operator marks hazardous area if needed
Localisation of hazardous area of chemical catastrophe	It is counted based on the proper formula
Spreading of first contamination plume	It is counted based on the proper formula
Showing the nearest hospital	Operator directs ambulances to the proper hospital
Receiving data from the TSP database	Operator receives data about toxic substances if needed
Receiving data from the equipment database	Operator receives data about specialised equipment if needed
Receiving data from the track database	Operator receives data about vehicles available if they are needed

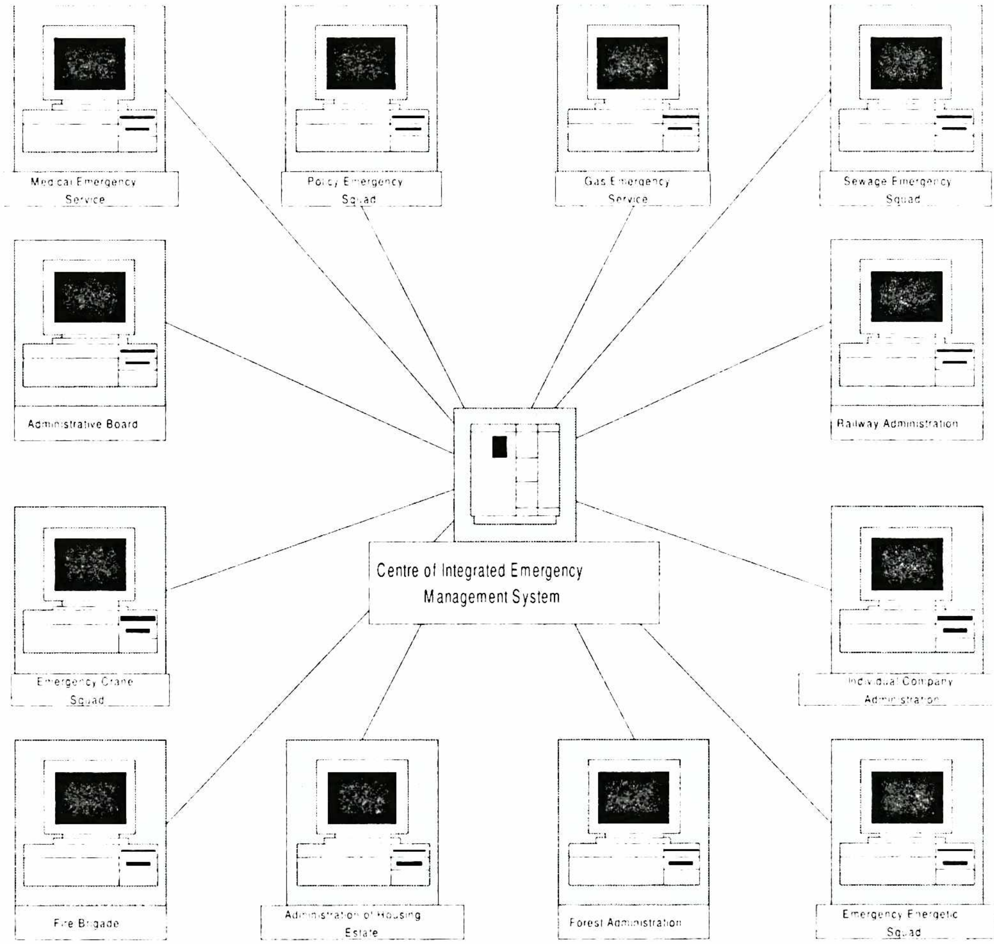

Figure 3. *Architecture of Integrated Emergency Management System network*

4. Software description

The IEMS data

Basing on project design a program is realised on a limited data set. It contains data of a part of Gdansk city — districts Nowy Port, Stogi with Krakowiec, Przerobka. The program is written in ArcView (Figure 4), but finally it will use ArcInfo 7.0.

According to the design of the IEMS data types were divided into groups with data dictionary. Each group has assigned a layer of information (coverage) in the GIS software environment (ArcInfo/ArcView). Table 3 presents a structure of data representation in creating the IEMS.

Table 3. *Structure of data representation in the IEMS.*

Name of entity	*Type*	*Spatial type*	*ArcInfo*	*Coverage*
building	spatial	area	polygon	Building
building entrance	spatial	point	label	Building
type of building	no spatial	alpha	DBMS	Typeofb.data
street axes	spatial	line	arc	Street
streets poly	spatial	area	polygon	Street
street name	no spatial	alpha	DBMS	Streetn.data
type of street	no spatial	alpha	DBMS	Street
rail axes	spatial	line	arc	Rail
railway station	spatial	point	label	Rail
owner	no spatial	alpha	DBMS	Owner.data
water bodies	spatial	area	polygon	Water
fire departments	spatial	area	polygon	Spec_service
hospital	spatial	area	polygon	Spec_service
medical assistance	spatial	area	polygon	Spec_service
policy	spatial	area	polygon	Spec_service
specialised service departments	spatial	area	polygon	Spec_service
telephone boxes	spatial	point	label	Boxes
specialised equipment	spatial	area	polygon	Spec_equp
vehicle	no spatial	alpha	DBMS	Vehicle.data
type of vehicle	no spatial	alpha	DBMS	Vehicl1.data
chemistry	no spatial	alpha	DBMS	Chem.data
green area	spatial	alpha	DBMS	Parks.data
school buildings	spatial	area	polygon	Mu_facility
school entrance	spatial	point	label	Mu_facility
nursery buildings	spatial	area	polygon	Mu_facility
nursery entrance	spatial	point	label	Mu_facility
industry	spatial	area	polygon	Industry
electricity	spatial	area	polygon	En_facility
hazardous materials mapping	spatial	area	polygon	Storage_ch

The program allows searching the event place, fixing the shortest path for emergency cars, using external databases. These databases contain data of specialised equipment resources, toxic substances list and others.

An officer taking a signal has a possibility to analyse it. Analysis means localise the place of an event and a person giving this signal. Nowadays, in Poland we drive the process of giving numbers to public telephones so it is possible to identify and localise every phone call.

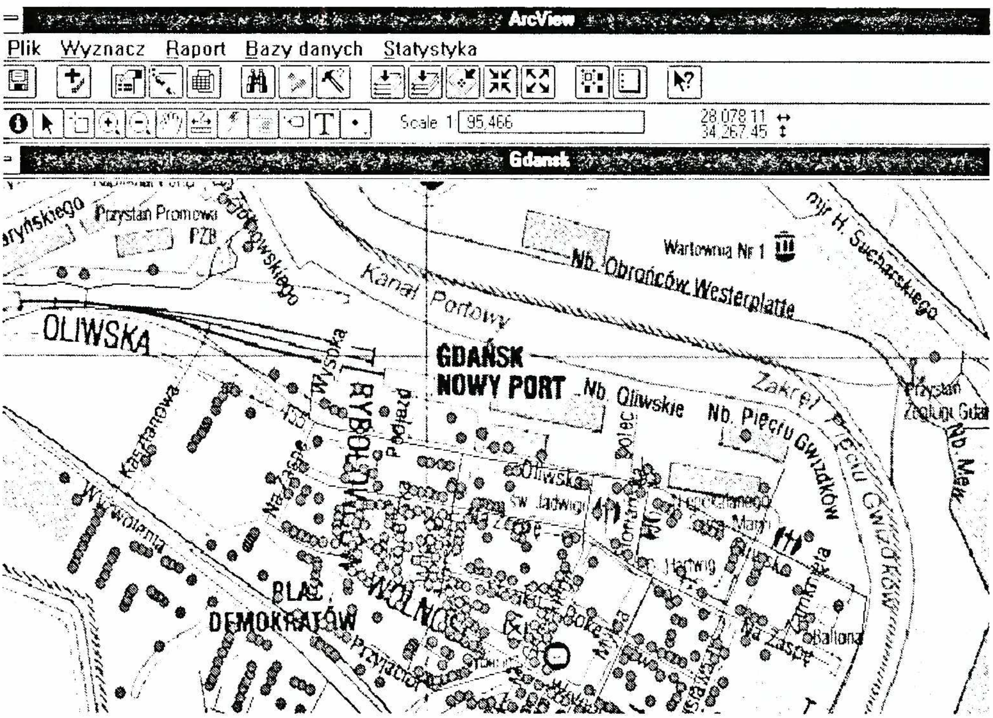

Figure 4. An example of the system data

The database of address points is supported by very precise information about buildings. The most important are data about installations. Identification of installation types within the emergency area allows to call proper services. The program, after inputting necessary data giving an approximate address of the event place and eventually telephone number from which the signal comes, shows on the map the approximate zone of emergency. Additionally, we can see a list of services which could take part in the rescue action, the layout of an object, and its plan.

In the case of local threat caused by toxic substances options of calculating the radius of contamination zone, first contamination plume and second contamination plume according to meteorological conditions are available.

Options of generating report from rescue action trace (build basing on Central Fire Brigade pattern) are available too. Additionally, an operator of the emergency system can create different statistics for some periods of time.

5. Summary

The GIS technology gives an excellent possibility to create a user-friendly, effective system for emergency management in a city. The main result of our project is a set of guidelines for proper implementation of the IEMS in the GIS environment in Poland. Our test implementation was performed with part of Gdansk city data. This helped us to verify most of our guidelines. We prepared our solution based on our own experience and after interviews with specialists, especially from the Central Fire Brigade in Gdansk, so we believe it will be suitable for the future development of such systems.