Computer network based decision support system for emergency response in case of chemical accidents

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Abstract

A computerised system for emergency planing, handling safety oriented data and decision support system in case of chemical accident has been described in the paper. The system can be used for diagnosis and prognosis of emergency situation by estimating endangered areas for a broad scope of scenarios, taking into account potential consequences for people and environment. The important part of the system is support of emergency response: automatic alarming of personnel, assessing quickly required forces and means and assisting in action to be taken, by the co-ordination staff, responders and endangered personnel. The technology used in the system is based on distributed network computer capabilities allowing for fast exchange of information and presentation of results on digital maps available on Web server. The system takes also into account plant specific data (safety-related design, operational and organisational information) and collects real-time data from various monitoring systems. As the system can be used for training and simulation of any emergency situation it is very useful as an emergency preparedness tool as well. The first version of the system was installed in one of the biggest chemical plant in north-western part of Poland Chemical Works "POLICE".

Introduction

The Chemical Works "Police" (ChWP) is the biggest fertiliser complex in Poland. The activity of the ChWP covers: ammonia production and storage for the needs of fertilisers production and for sale (raw materials: natural gas of high content methane, nitrogen), production of sulphuric acid, phosphoric acid and fertilisers. Ammonia is transported from the sea port to the storage tanks by means of an import system made up of a breasting island and an overground pipeline of 5 km length. The ChWP are located about 3,5 km from the centre of the neighbouring town Police (about 20 000 inhabitants), 18 km from Szczecin, - the capital of the region (about 400 000 inhabitants) and 18 km from the German-Polish border.

List of dangerous chemicals used in the ChWP, apart ammonia (gaseous, liquid)- max. ~ 21 000 t also includes: sulphuric acid - 41 000 t, phosphoric acid -19 000 t, combustible gases (methane, synthesis and process gases)- 60 000 t, hydrogen -180 00 Nm^3 /h, furnace oil - 3 600 t, machine and turbine oils - 200 t, diesel oil -100 t.

In case of an emergency the first echelon forces are composed of on-site Internal Fire Brigade (IFB), Emergency Service for the Chemical and Technical Rescue (ESCHTR), Department Groups for Evacuation and Fire Fighting (DGEFF). The ESCHTRs are not organisationally separate units. Their members are regular employees of selected installations/departments/sections. DGEFF are established in each organisational unit of the ChWP, and they have determined tasks regarding chemical, technical and fire rescue in the given area or unit. The second echelon forces are the Emergency Squads of the State Fire Service (SFS). Forces of the III-rd echelon are Militarised Squad of Chemical Rescue and Technical Rescue Squad of Civil Defence. In case of an emergency with impacts to surrounding communities the rescue action on the area of the ChWP is co-ordinated by the commander of IFB and the rescue action beyond the ChWP premises is organised and co-ordinated by the State Fire Service.

Plans for the emergency operations, which are in place, account for tasks of: factory's dispatcher, shift managers in the departments/sections, internal fire brigade, medical service, industrial guard, ESCHTR, DGEFF and of the team co-ordinating emergency actions.

For communications during emergencies a LAN (FDDI technology), internal telephone lines system, radiotelephone system, pager system and local broadcasting can be used.
The monitoring systems of the chemical works include: chemical, fire and other hazards monitoring systems; an on-site meteorological station and hydrological monitoring; alarming and TV monitoring systems.

The features of the ChWP:

- large number of process and storage installations,
- large quantities of dangerous substances, produced, stored, loaded/unloaded and transported by pipelines (on-site and off-site),
- large number of employees,
- various on-site rescue-services to fight emergency,
- siting of the ChW "POLICE" (vicinity of: a large river estuary, the national border, inhabited areas and the capital of the province)

demand development a comprehensive computer-aided system for emergency planing, handling safety oriented data and decision support during emergencies.

For these purposes a computerised system SWAR has been developed and implemented. The system has been designed for:

- providing capabilities for computer aided emergency planning,
- providing sufficient means to co-ordinate emergency actions via a computer network,

- easily handling diversity of hazardous sources and scenarios by: assessing releases (substances and energy), predicting dispersion in the environment and assessing consequences,
- assessing quickly required emergency response (forces, vehicles, equipment),
- presenting results in a form of text, diagrams, drawings and maps,
- providing an easy access to the relevant information via a WWW site,
- providing means for training and simulation of any situation.

The most important functions of the system SWAR are the following:
- diagnosis and prognosis of emergency (real time estimates of endangered areas, transport in the environment, potential consequences to people and environment),
- support of emergency response with use of a distributed computer network,
- automating alarming of personnel to be involved in emergency actions,
- assisting in action to be taken, by the co-ordination staff, responders and endangered personnel with use of computer network,
- collecting real time data from chemical meteorological, hydrological, fire detection and visual monitoring systems, and from measurements of parameters determining the state of buildings and waste dumps,
- GIS based graphical presentation of data,
- collecting and updating plant specific data (safety related design, operational and organisational information),
- generating subject oriented layers of digital maps.

In subsequent sections all these elements are described.

Information handled by SWAR

The main objective of an on site emergency plans in case of a chemical accident is to minimise consequences for people and environment by quick undertaking of appropriate emergency action. This in turn depends strongly on scenarios of the accident. It is particularly important that well-defined duties of particular services and co-ordinator are precisely described. In case of accidents with off-site consequences there is also a need of a co-operation between local and on site authorities and rescue services. Therefore the following groups of information are essential to account for by any decision support system supporting decision making in an emergency:
1. Regulations in force, which constitutes the basis for developing preparedness plans.
2. Information about localisation and types of activities in chemical plants.
3. Potential accident scenarios and their consequences for people and environment.
4. Databases containing information on available means and forces that can be used in rescue operations.
5. Rules for proceeding in case of an accident.
6. Rules to follow up actions.
7. Diagrams and digital maps.

As a result of these demands the computerised system SWAR has been designed to integrate the following elements:

1. Databases containing information about: sources of hazards (materials, objects), employees in particular objects and forces and means to be used in rescue actions. These data should be integrated with digital maps under a GIS system.
2. Database of basic chemical and physical properties of chemical substances, important for analysis of hazards.
3. Numerical maps of the plant and its vicinity.
4. Module for collecting information from meteorological services and other real-time monitoring systems, including monitoring of concentration of dangerous substances
5. Modules for diagnosis and prognosis of accident scenarios, which use information from real-time monitoring systems and/or simulation programs.
6. Module for visualisation of pollution transport in the environment, indicating endangered areas, and for preparation of reports.
7. Module for alarming personnel and warning people in the vicinity of the plant, and inform appropriate authorities.
8. Module for support of co-ordination of the action and exchange of information between groups of rescue teams.

Programs for analysis of accident scenarios implemented in the system SWAR cover a variety of emergency situations related to possible releases of toxic materials, explosions and fires (solid material fires, pool fires etc.). For completeness the contamination of water bodies is also taken into consideration, particularly in case of floods.

The modules assisting in co-ordination during action are based on emergency plans of the ChWP, which are in place and account for tasks of: the factory's dispatcher, shift managers of the departments/sections, internal fire brigade, medical service, industrial guard, ESCHTR, DGEFF and of the team co-ordinating emergency actions

The system is designed so that it can co-operate with all elements of safety features already implemented in the plant and with all the actors of the scene of emergency actions.

Structure and functions of SWAR

The system consists of a graphical user interface, databases, a message exchange server, and modules for calculating emergency zones.
The graphical user interface integrates all elements of the system and makes it possible to access to all functions and tools of the system. These are:

- digital map of the plant and its vicinity, available on a Web server,
- document browser, which can be the Web browser,
- control lists containing description of tasks for persons taking part in emergency actions,
- tools for sending and receiving messages,
- history of message exchange, i.e. lists of received messages, which can be useful for further analysis of how the action has been undertaken,
- tools for creating different emergency scenarios,
- tools for administration of the system.

Digital maps can be created and edited in any GIS systems, like MICROSTATION, ARCINFO or MAPINFO. These maps are used for visualisation of the current situation during the action. The user can put pictograms on the map, then the updated map is automatically available for all users of the system via network. All modules generating emergency zones produce additional layer for displaying on maps.

All the documents are available in the html format, so any Web browser can display them. Additionally, the graphical user interface contains an embedded form of Internet Explorer browser.

The mechanism of control list serves not only for controlling progress of work of particular tasks, which should be fulfilled by rescue teams, but also prompts what activities should be undertaken. Appropriate control lists must be prepared earlier - there is a module in the system, which can be used for this purpose. During the action a report file is automatically created containing all events, that have occurred as well as the progresses of realisation of tasks to deal with them.

The exchange of messages is an essential part of the system. The user can send text information to the action co-ordinator who can send received messages to all other users of SWAR. Messages have different priorities – these ones with the highest priority are served first by the message server. All received and sent messages are stored in files, what enables analysis of undertaken action later.

There are number of administration tools in the system like synchronisation of clocks and pictograms, request for changing co-ordination and additional configuration utilities.

Apart from the visualisation of emergency zones the system can also generate graphs showing concentration of pollutants in function of time. Information from monitoring systems like meteorological station is continuously displayed and updated by the system.

Most data essential for the systems are stored in databases concerning rescue equipment, chemical and physical properties of chemical substances, personnel data of potential actors of the emergency scene, technical objects and their attributes. It should be emphasised that essential information can be defined by introducing attributes for map objects. In such a way any information can be automatically related to graphical objects on the map and can be accessible via the graphical user interface. On the other hand one can reach the same information via the Web browser.

There are also a large number of data stored in html files - the most important are:

1. Organisational diagrams.
2. Address book.
3. Information about external forces and means, which can be eventually used in the emergency action.
4. General rules concerning alarming schemes, communication lines, medical help, evacuation etc.
5. Regulation and related documents concerning emergency preparedness and response.

The documentation can be also useful in preparing control lists, during the action as a general source of information of various types and after the accident while analysing the undertaken action.

The system has a specially designed scheme of message exchange. It allows for fast exchange of information between personnel, rescue teams and action co-ordinator. In consequence it supports co-ordinator's activities and improves his efficiency. Additionally all documentation from the action is created on-line from all reports. Exchange of messages is based on the TCP/IP protocol. One of the computers of the network operates as a message server with the main task to receive and send messages. Clients' computers can exchange messages after logging into the system. During the action one of the computers plays the main role – the co-ordinator can filter information and send essential messages to those who its really need. The general structure of the system SWAR is shown on Fig. 1.

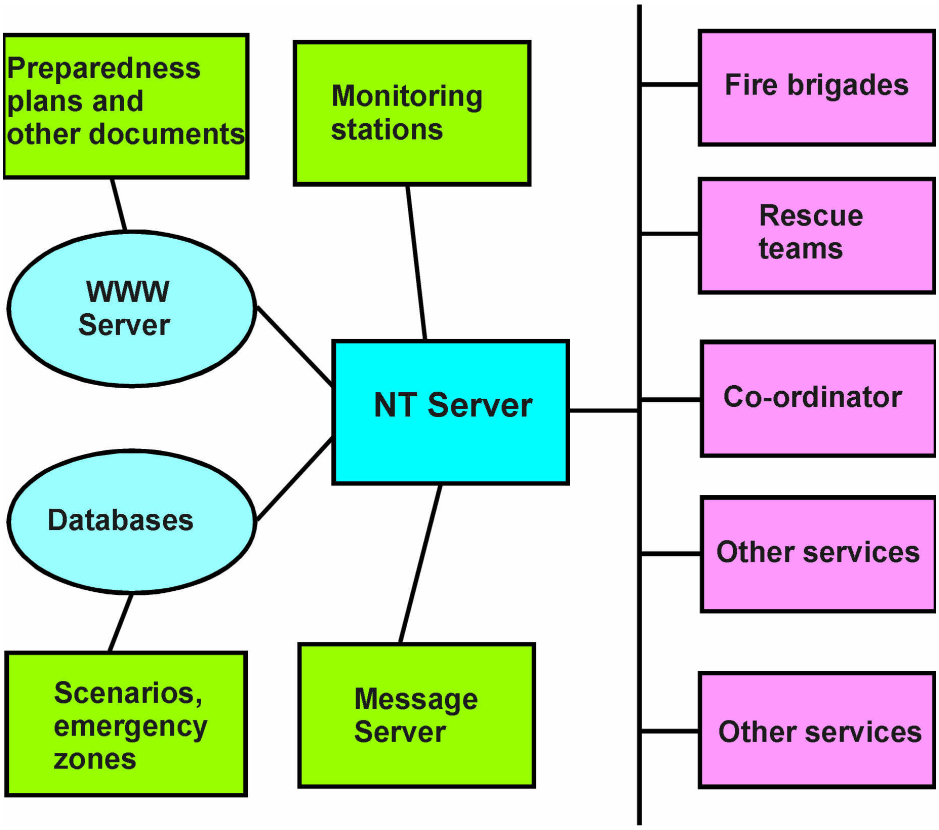

Fig. 1 Structure of the system SWAR.

In SWAR two groups of programs for analyses of accident scenarios have been implemented

1. Package of programs for fast analysis in real-time.
2. Package of programs for advance analysis, that demand longer time of calculation - it can be used for pre-calculations of accident scenarios and for training purposes.

The user must define several input parameters and choose appropriate type of calculation (type of the accident: fire, explosion or release of toxic materials, amount of the released substance and the location of the release).

In case (1) two types of programs can be used:

- programs basing on the methodology developed by the Civil Defence,
- simplified models of the DISMA package, developed by TÜV Anlagentechnik, Germany and used for calculating transport and consequences related to a wide range of scenarios of released chemicals or energy, so that emergency zones can be determined in real time.

These programs were verified in field experiments.

Several programs for advanced analysis have been also implemented including diagnosis of meteorological fields for dispersion calculation in case of variable wind fields and detailed analysis of propagation of dense gases with all the relevant phases and physical processes accounted for. They are based on models developed by the SRD-UK and the Risø National Laboratory in Denmark and verified in field experiments.

The system can operate in three main modes (see Fig. 2):

- administration,
- preparation of emergency plans,
- action.

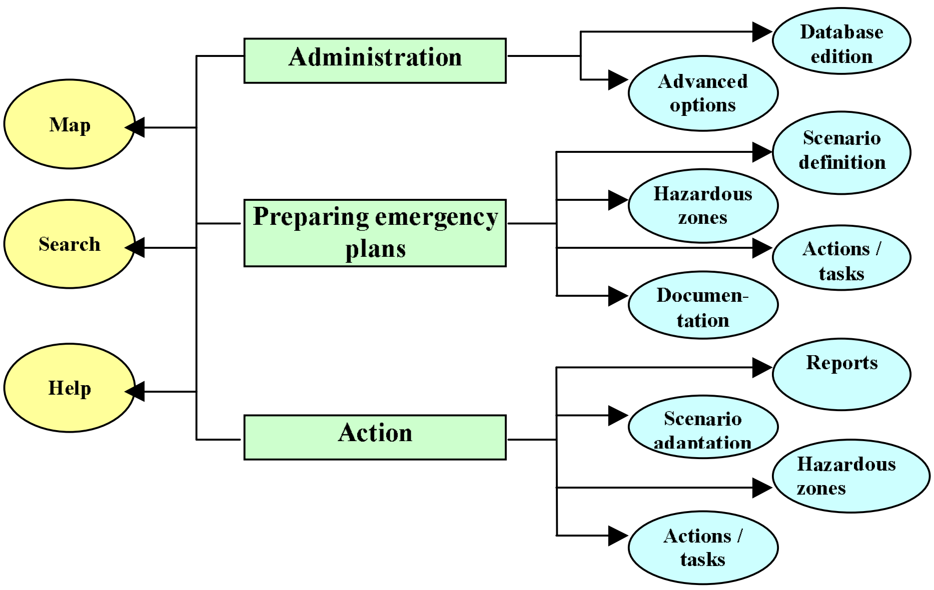

Fig.2 Modes of operation of the system SWAR.

In the administration mode the user can operate on databases, depending on his competence. In particular the following operations are possible:

- searching information on objects, chemicals, sources of hazards, forces and technical equipment relevant for rescue actions, etc. ,

- browsing and edition of database records,
- defining new attributes for objects and modifying them,
- importing data from other databases.

In case of geographical objects user can make operation by indicating objects on the map. Thus this mode allows for updating:

- information about objects, their spatial localisation and whole plant infrastructure,
- information about protected objects, elements of environment etc.,
- data about hazard sources,
- data about forces and means, which can be used in the emergency action,
- basic chemical and physical properties of danger substances,
- experience from other accidents.

In the mode of preparation of emergency plans the user can:

- define emergency scenarios for particular objects,
- determine hazard zones,
- define rules to proceed in case of different types of accidents and create templates of documentation to be used during emergency actions.

This mode allows also for various experiments and exercises with usage of all models of accident analysis implemented in the system.

The most essential part of the system is the action mode. In this case earlier prepared emergency plans plays important role. The co-ordinator of emergency actions can:

- determine hazard zones,
- define what forces and means should be used in the action,
- make use of message exchange system to control the situation.

The hazard zones can be calculated in real time using the module for fast dispersion and consequence calculations. One can also make use of the pre-calculated scenarios, stored in the database. The most optimal approach is to select an appropriate scenario from database and modify necessary data to adjust to the current situation. Meteorological data can be delivered automatically from measurement stations or defined by the user of the system SWAR.

The information is available in form of html documents or control lists and can be easily accessed on the Web. Data given in form of control list allows for fast assessment of the current situation. For any object it is possible to check the status of undertaken tasks and in case of need of additional support the co-ordinator of actions is able to make appropriate decisions.

All received and sent messages are stored in databases. The messages contain the following information:

- who reports,
- time and place of report,
- short description of reported event,
- additional comments.

Finally the co-ordinator can estimate consequences and prepare appropriate reports.

Software solutions

The main idea of the SWAR design is treatment of any element of the system as an object of an appropriate class. The class is defined by its attributes, which means, in case of creating new objects, that their all-relevant attributes are automatically inherited. In order to define an attribute it is necessary to define value types that apart from typical types (like numerical or string) can be html documents or more generally URL addresses. Hence creating the system is to a large extend based on defining classes, their attributes and objects.

The geographical objects play a special role in the system as many data are related to them. The objects are grouped into layers, which typically correspond to classes. Any geographical object has few pre-defined elements like name, identification number or number of person (which can vary during the day). The information stored in databases can be linked to the objects (for example equipment data, personnel etc.). There is still a possibility to add some attributes to specify other properties. For instance the user can define attribute, which contains photography of the object in form of html page. In case of such necessity the administrator can define new class by introducing its name and linking appropriate attributes to it. Then the user can add new objects of this class to the system. All these operations can be done via the Web browser.

One of the important things is the way to find relevant information. The user can search databases by object's name, attributes and their values, substances, persons, equipment and identification numbers.

A MS SQL Server 6.5 database was used in case of the system SWAR. A special module for management of databases was created. This module is a CGI application, which dynamically generates Web pages. There is no need to install any additional plug-ins or any other executables.

In order to synchronise information during the emergency action, a dedicated protocol for message server was been developed, based on TCP/IP transport layer. It can be implemented practically on any machine in the network. Apart from transmitting messages the message server is also responsible for updating information on digital maps. Besides the message server transmits monitoring data from measurement stations (e.g. meteorological or environmental monitoring readings) to the rest of the system.

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