COMPARISON OF SIMULATORS USED FOR EDUCATION AND PRACTICAL TRAINING OF THE CRITICAL INFRASTRUCTURE STAFF

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Abstract: *This article deals with the issue of practical training of the management staff during emergency events in the frame of critical infrastructure. The addressed event is frost that caused a large power outage with consequences overlapping other sectors. An extensive power outage is one of the most serious natural threats to current society. Practical training is an efficient tool for developing abilities and practical skills of crisis staff members. The goal of the exercise carried out was to test used simulation tools and their possible usage in practical training. During the exercise, deficiencies in the simulator processes have been identified.*

Keywords: constructive simulation; exercise; crisis scenario; critical infrastructure; preparedness.

INTRODUCTION

Simulation and practical training using simulation technologies have become increasingly widespread throughout the world. Expansion of simulations is even more significant with both development of technologies and growth of computing performance (Shelomovska et al., 2016; Delgado et al., 2016). Flood waves spread after heavy rainfall, the effect of laser use on air traffic safety in the vicinity of airports, spread of dangerous substances, efficiency of military ammunition and other processes are being simulated. Simulation is also used in practical training and skill acquisition of the employees. Crisis management members as well as crisis staff members at different levels of management are no exception (Hubáček & Vráb, 2012). Staff training is an important area where possibilities of simulation usage are not and will not be used enough in the near future (Delgado et al., 2016).

Computer simulation enters the area of staff practical training only at a slow pace. This is probably due to a lack of confidence in new technologies as well as the relatively high acquisition costs for building complex simulation centres. For this reason, complex simulators for staff practical training or crisis staff training are available, with exceptions, only in military facilities (Hubáček & Vráb, 2012; Hubáček & Řezáč, 2013).

1. CURRENT SITUATION ANALYSIS

This chapter deals with the issue of tactical and staff exercise and increase in the level of development of professional education and skills of crisis staff members. Attention is paid both to the possibilities of software support to the exercise as well as to evaluation of the already executed national staff exercise with involvement of all interested parties, including critical infrastructure entities (Urban et al., 2017).

1.1 Organised exercises

Emergency situation preparedness or crisis situation preparedness significantly contribute to providing efficient and rapid response and damage minimization. Acquiring practical skills and knowledge enables successful response to the emerged situation. In the Czech Republic (CR), the issue is dealt with by the Integrated Rescue System (IRS) Act (Act 2000a), which, however, addresses the compulsory exercise as well as practical training only of the IRS components. Neither the Critical Infrastructure Entities, nor the Crisis Staff members are subjects to the training obligation (Act 2000a). According to the Crisis Act (Act 2000b), the liaison security officer and the management of the company are responsible for the preparation and implementation of practical training.

Energy critical infrastructure entities that undertake education as well as practical training even if no regulations force them to do so represent an exception (Oulehlová et al., 2015). These companies are aware that their components are very important and that preparedness for addressing both emergency situation and crisis situation is necessary (Urbánek et al., 2015). Energy Critical Infrastructure Entities implement a broad scale of training without use of any simulation tools. Preparation of the training consists of theoretical staff instruction or practical exercises in situ, so-called live simulations which are financially and organizationally highly demanding (Hubáček & Vráb, 2012; Oulehlová et al., 2015; Delgado et al., 2016).

1.2 The effects of a power supply failure

In the case of a long-term power outage, consequences for the current technology based society would be enormous. Therefore, an important critical factor is the provision of protection, functionality and reliability of energy critical infrastructure.

Extensive long-term power outages are known both from abroad and the Czech Republic. The biggest European power outage was the blackout in Italy, which affected 57 million inhabitants in 2003. The cause of the outage were overloaded power lines from Switzerland, and due to incorrect interference after the failure, the domino effect followed as well as the interruption of all other lines. This power outage was one of the largest in the world (Sesame, 2011).

In the Czech Republic, the power supply was cut in 2007 due to the Kyrill tornado and in 2008 during the Emma windstorm. Outage was caused by strong wind and trees fallen on the power lines. This resulted in over one million households disconnected from the electricity supply. In December 2013, thirteen high-voltage masts fell due to the icing, and the electricity supply was cut off for almost ten thousand people.

The dependence of individual sectors on energy infrastructure is obvious. Power outage causes a cascade effect in other sectors (Luiijf et al., 2009). In the context of the research into the relations between critical infrastructure sectors, the energy sector has been considered a key one in ensuring the functionality of critical infrastructure. The interconnection of energy critical infrastructure with other infrastructure sectors was analysed in detail in the article Preparedness of Critical Infrastructure Subjects in the Energy Sector for Crisis Situations (Oulehlová et al., 2015).

1.3 Selected simulation tools

Various computer programs can help the instructors during preparation of training. They enable better graphic support of the solution, practice various ways of dealing with different situations and ways of command and last but not least they can be a prerequisite for various roles. The environment of these programs increases the effect of training which is then more realistic and students can remember the learned things better. Selected simulation tools which were suitable for realization of the exercise with the “Frost“ topic with the subsequent power outage were used within the preparation of the practical exercise.

1.3.1 SIMEX

It represents a system of constructive simulation for the computerised generation of forces and creation of synthetic environment. Originally it was designed for the use of army but the version for the components of the Integrated Rescue System called SIMEX has been developed as well. The simulator enables to practice management on the tactical, operational and strategic levels. Modelling of various emergency situations and dealing with them is possible in this environment (Figure 1).

Environment in the simulator is ensured by the combination of terrain database created from the detailed geographical data, model of weather and other dynamic environmental models. Terrain database contains all common objects in the countryside (bodies of water, roads, built-up areas, vegetation, relief, type of soil and other objects). Individual objects have predefined features influencing simulation of their own entities in relation to their purpose. Weather editor enables to set basic parameters (date and time, air temperature, velocity and direction of the wind, type and intensity of precipitations, humidity and pressure of air, type of cloud cover, light intensity etc.). Some of the parameters are mutually interlinked based on the actions happening in the atmosphere known from meteorology. Dynamic models of environment enable modification of the countryside with objects and phenomena which can change their form in the course of time (Figure 1). There are accidents simulated in great detail as well as a vast database of forces and means. Program puts more emphasis on the correct execution than on graphic output and it is aimed at the group of trainees as well as at an individual (Hubáček & Řezáč, 2013; Urbann at al., 2017).

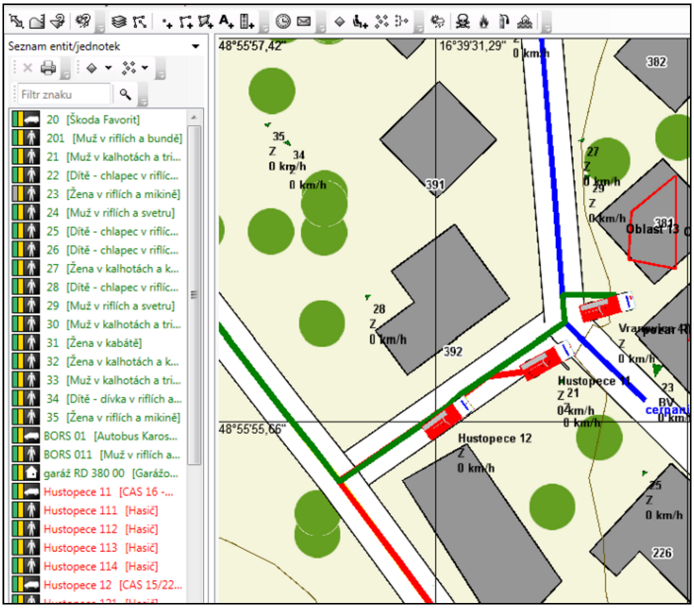

Figure 1. Environment of program SIMEX
Source: Own work based on program SIMEX

Concept of the program is suitable for the use in practical training of solving emergency events with the mutual cooperation of the intervening units.

1.3.2 Virtual Reality Training Software for Safety and Security

The creator of this environment is E-semble company which headquarters are in Netherlands. These programs serve to address emergency situations in preparation and practicing of practical abilities.

The environment of the Virtual Reality Training Software for Safety and Security (XVR) Crisis Media program serves for training correct and quick development of public awareness in emergency situations (Fig. 2).

Program XVR Resource Management aims at operational and strategic level of command. One of the components is a map with the survey of all already occurred situations and after the click on it, it is possible to determine the number of forces and means necessary for the intervention. Later transportation of the patient into the hospital follows, where it is possible to set the possibilities of treatment (E-semble, 2017).

Figure 2. Program XVR environment
Source: Own work based on program XVR

Module XVR On Scene serves the purpose of the individual components intervening in emergency situations and can show the progress on the predefined scenarios. Thanks to this program, it is possible to model a great number of emergency situations which can be dealt with subsequently as if the trainees were present at the place of accident. This program is also used by professional teams in several countries - Netherlands, Great Britain, New Zealand, Australia, Taiwan, China and Czech Republic. It is well suited for practical training of intervening units (E-semble, 2017).

1.3.4 3D Flood Simulation program

A computer program called 3D Flood Simulation is specialized software developed by the non-profit Centre for the Safe State organization and is focused on training tactical activities of the IRS components at emergency situation related to floods. Due to its variability, any emergency situation scenario can be created in the simulator. It is possible to model representative terrain including vegetation, static objects and water flow with the possibility of flood situation development in the application (Fig. 3). Simulator model allows for variable setting of simulation activities of crisis management staff, forces and resources dealing with extraordinary events dislocation, activities to carry out population evacuation, etc. (Kavan, 2015).

The simulator allowed creating a sequence of steps corresponding to the actual processes of the crisis management bodies in the case of dealing with emergency situation. Scenarios make use of intuitive application control, so most operations can be done using classic application control. The scenario is divided into chapters; each chapter contains a combination of cards representing one sequence of actions in the entire simulation.

Figure 3. 3D Flood Simulation environment
Source: Own work based on program 3D Flood Simulation

Creating Scenarios in the 3D Flood Simulation program can be divided into the following stages:

- Creating an abstract scenario model – forming a simplified description of the studied reality.
- Creating a simulation scenario model – recording an abstract scenario model in the form of a program.
- Verification and validation – verifying the scenario model correctness.
- Simulation – experimentation with the simulation scenario model.
- Analysis and interpretation of results.

These stages form a good basis for creating environment and emergency situation frost scenarios with large-scale power outage.

1.3.4 Virtual Battlespace

Virtual Battlespace 3 is an interactive virtual tactical simulator, which is based on the game engine "Real Virtuality 2" developed by Bohemia Interactive. The simulator uses computer games technology to teaching and training. It is a flexible solution for simulation training scenarios, missions and more. In addition, Virtual

Battlespace 3 Virtual Training Kit encompasses a full feature suite of products that enable rapid content creation, HLA/DIS (High Level Architecture, Distributed Interactive Simulation) integration, and training assessment. Virtual Battlespace 3 simulates any environment to help trainees learn techniques, procedures and develop communication and decision-making skills (Kozůbek, Čech & Flasar, 2010).

Virtual Battlespace 3 expands on its predecessor Virtual Battlespace 2 by improving the Virtual Battlespace open architecture, providing faster performance with our multicast system, and introducing a new, more modern-looking user interface. VBS3 in the version of Virtual Training Kit includes many modules and other plug-in applications. To carry out experimentation by modelling and simulation, it is possible to use the Virtual Battlespace 3 tools, such as Scenario Editor and Application Scripting Interface, which are two of the most significant ones.

Scenario Editor – a well-designed exercise is essential for effective training and realistic experimentation. The Scenario Editor sets the standard for scenario creation (Kozůbek, Čech & Flasar, 2010; Urbánek et al., 2013).

The use of simulation process in crisis management during practical training dealing with emergencies is very extensive. Simulator Virtual Battlespace 3 can be configured for civilian use and practice to training communication and teamwork. The only drawback is the lack of deployment of civilian entities, adding to the simulator Virtual Battlespace 3 would cost a lot of money. Therefore, it is currently better to buy a simulator specifically designed for civilian use, but Virtual Battlespace 3 inspired when creating scenarios.

2 APPROACHES AND METHODS

Modelling cannot capture the reality itself, but rather, with a simplified view, it looks at a certain part of the real process. Simulation is often used for the training of civil as well as military employees. It is used in the case when it is too expensive or too dangerous for the trainees to use the facilities in the real world. In such situations they spend time by learning valuable experience in the “safe“ virtual environment. The advantage is also represented by mistakes which the system during the training enables in safety-critical systems. The accuracy and veracity of the model depends on the modelling method used.

2.1 Computer simulation

A computer simulation method was used to prepare a series of practical exercises as well as for the actual implementation. This is an attempt to model the real world or hypothetical situations with the help of a computer to be able to study this system and trace how it works. The behaviour of this system can thus be predicted by changing the variables (Zehe et al., 2016). The behaviour of the model in the simulations varies depending on the settings of the original parameters taken from the real environment (Hubáček & Řezáč, 2013). There are many different types of computer simulations, the common feature of which is the attempt to create examples of representative model scenarios for which a complete list of all possible conditions cannot be made or is not available (Zehe et al., 2016).

The most appropriate form of computer simulation was considered for practical exercises preparation. It was selected from the following categories:

- "Live" simulation (where real people use simulated (or "false") facility in real world);
- "Virtual" simulation (where real people use simulated equipment in simulated world or virtual environment), or;
- "Constructive" simulation (simulation where people use simulated facilities in the simulated environment). Constructive simulation is often referred to as "war" one, because it is similar to strategic war games in which the players command armies of soldiers and war machines which can be usually moved on the playing area.

Constructive simulations where simulated entities are controlled by simulated operators were chosen as the most appropriate one. Constructive simulation is a kind of simulation where the model contains everything needed to replace the original during the simulation, including the one that involves humans (Ludík & Ráček, 2011). In constructive simulation, man is represented by a submodel. Decisions of these simulated individuals are applied in the actions of constructive simulations. Constructive simulations are used at different resolution levels for different types of operations in addressing emergency situation (Hubáček & Vráb, 2012).

2.2 Requirements on technical equipment

Simulation programs are extremely demanding on the hardware quality and technical maturity on which the simulation is run. They require appropriate technical equipment and specified work environment. All simulators use a modern 3D environment known from computer games, allowing participant to "enter" the environment and view the emergency situation from all sides and angles. The advantage of 3D environment is above all its great visuality. Only the SIMEX simulator uses classic 2D display and 3D display is used as an optional supplement. The drawback of 3D environment is its high demands put on computing power and the danger of slowing down and jamming of the simulation during controlling multiple entities. For smooth operation of simulations, it was necessary to provide workstations with the following requirements:

- Intel Core i5 3470 processor @ 3.2GHZ (4 CPUs) / AMD X8 FX-8350 @ 4GHZ (8 CPUs).
- RAM min. 8GB.

- NVIDIA GTX 660 2GB graphic card / AMD HD7870 2GB.
- 100% DirectX 10 compatible sound card.
- DVD drive.

2.3 Exercise scenario

From the tools for simulations, modelling and support of decision-making processes in crisis management, only those programs which met predefined criteria were analysed and included in the shortlist. These criteria were determined based on the experience of the research team from the area of information support and after consultations with experts in the area dealing with development of simulation tools. The basic criteria were: functionality, usability in solving emergency events, practical training of the teams and individuals, possibility of implementation of outputs from other tools and possibilities of editing scenarios. During the analysis of available simulation tools, some criteria were reconsidered and complemented with other characteristics which were required from the simulation tools.

The intention of the series of exercises was to verify and compare the usability of individual simulation tools in the practical training of crisis management staff. The priority objective of both the scenario and the exercise was not the preparedness of the IRS components, but the practical training and verification of the preparedness of the crisis management staff at the level of the region, the municipalities with extended powers, or the mayors of the municipalities and administrative authorities with extended territorial competence and other entities involved in emergency situation addressing. The aim was to verify activities, communication and cooperation of crisis staffs. A scenario that was implemented in selected simulation tools according to the possibilities was prepared (Oulehlová et al., 2016).

Figure 4. High-voltage masts collapsed due to icing
Source: GA Energo technik

The theme of the scenario was emergency situation, which took place in the Czech Republic in December 2013. Due to the weather conditions, a huge amount of icing occurred on the equipment in the outdoor environment. Thirteen high-voltage masts (Fig. 4) collapsed after overtaking the critical stability limit and the power supply to the nearby city was cut off. The local area where the icing caused tree falls on the roads and several villages cut off from the transport link was affected by these severe weather conditions.

The scenario was prepared and implemented with minor differences in the selected simulation programs. Workers of the Crisis Management Department who were expected to have the required knowledge in the field of crisis management were chosen as participants.

Trainers were assigned individual roles and provided with information about given roles in the scenario. They were given time to get familiar with the activities of the individual roles and for the studying of necessary documentation. Prior to the exercise, participants were made familiar with the basic functions of simulation tools and the communication system (Oulehlová et al., 2016). Since XVR, Virtual Battlespace and 3D Flood Simulation program simulation tools do not have their own communication systems, a communication system that is a part of the SIMEX simulator (Hubáček & Řezáč, 2013) was used in all exercises.

2.4 Evaluation of exercises

The analysis of the course of the exercise and overall assessment based on the record using support tools took place after the completion of the exercise. In the context of the simulator use, the major benefits were found in the field of call recording and recording the course of implementation of various activities of the participants. Moreover, various levels of the knowledge of crisis documentation and low level of its use have been found among the participants of the exercise. The exercises were evaluated from the point of view of the lecturers. The tutors answered the questions about user friendliness and complexity of individual simulators.

3 RESULTS AND DISCUSION

The exercise was going on for several days, with each day carried out on one selected simulation tool. The exercise took place during the month of April 2017. During exercise, attention was focused on communication. These are activities that are related to designing opening scenarios which lead to improving procedures and processes. Great emphasis was placed on the course of exercise preparation, because the exercise preparation, processing the schedule, including examination of contacts generally reveals significant deficiencies.

During practical exercises, the interaction between the intervening components was practiced. Depending on the emergency situation development in the simulator, other IRS units and components were gradually deployed (Fig. 5). In addition to the disposal of the fallen trees which number was gradually increasing and which threatened the nearby buildings, it was necessary to provide an access road for the company providing the repair of the fallen high voltage masts. It was important to ensure the movement of E.ON Distribution personnel who were performing a manual switchover of a replacement power line. Other assigned roles of the crisis staff, carriers, technical services, and other organizations performed activities within their competences.

Participants had to cope with unfavourable climatic conditions, poor road passability, technical problems and accident rates of vehicles that were simulated. Besides verifying the functionality of the environment depicting the real situation in 3D, other objectives of the exercise were to verify the setting of communication processes and links between the individual groups of participants, possibilities of their dynamic changes during the exercise depending on the development of the simulation, and last but not least, also the crisis management staff training itself (Hubáček & Řezáč, 2013; Zehe et al., 2016).

From the tools for simulations, modelling and support of decision-making processes in crisis management, only those programs which met predefined criteria were analysed and included in the shortlist. These criteria were determined based on the experience of the research team from the area of information support and after consultations with experts in the area dealing with development of simulation tools.

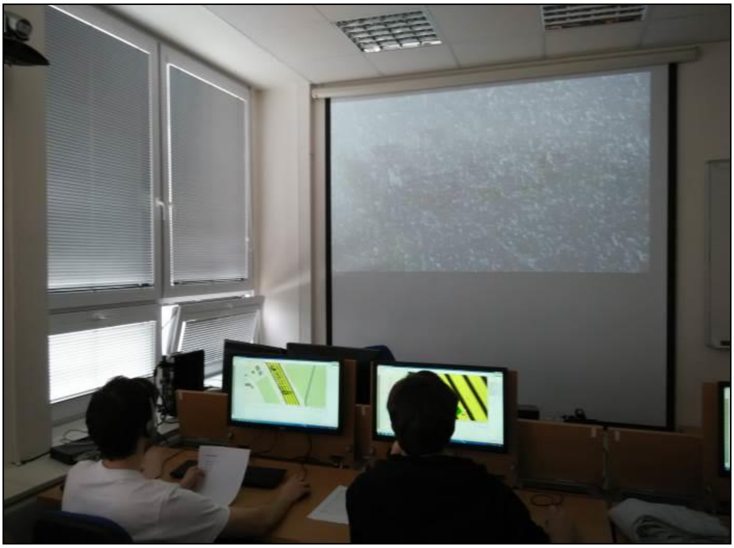

Figure 5. The emergency situation development in the simulator
Source: Own work

The basic criteria were: functionality, usability in solving emergency events, practical training of the teams and individuals, possibility of implementation of outputs from other tools and possibilities of editing scenarios. During the analysis of available simulation tools, some criteria were reconsidered and complemented with other characteristics which were required from the simulation tools. These added characteristics specified in more detail the choice of suitable simulators and made the original characteristics about what the simulator should meet, more accurate. Results of the evaluation can be seen in Table 1.

The XVR Simulation Tools and 3D Flood Simulation were a great benefit to the exercise. They showed the 3D scene of the emergency situation, and the intervention commander had an overview of what was going on at the scene. The disadvantage of these programs was the absence of integrated communication systems. During the exercise preparation, the possibilities of using freely available communication systems such as Skype were considered, but since this system does not allow recording, the idea was withdrawn. All simulations used the Astra communication system which creates part of the SIMEX simulation tool.

A great advantage of the SIMEX simulator was not only the above mentioned integrated Astra communication system, but also the possibility to control the process of moving of individual entities within the emergency situation addressing. These entities were moving according to current climatic conditions, and it was really efficient to modify the condition of the entities according to a defined scenario or the requirements of the exercise commander. On the one hand, emergency situation overall insight for the commander of the intervention was a benefit; on the other hand, this insight was counterproductive for other participants. They had the option of a complete overview of the emergency situation addressing ~~on~~ the monitors which they did not need and even though they were warned not to watch it, they violated the ban. This fact interfered with the exercise, because in a real environment the possibility of a complex insight in the emergency situation addressing would not be available.

Due to the observed positives and negatives, it is possible to conclude that all tested simulation programs have met the requirements put on them and are suitable for the practical training of the crisis staff members in the case of the disrupting of critical infrastructure elements. The most important benefit of the exercises carried out was the fact that the participants verified their theoretical knowledge and practiced practical skills in the processes of communication when addressing emergency situation.

Based on the results, a comparative table (Table 1) was compiled with the utility properties of the individual simulation tools where the most important properties and benefits of the simulation tools were listed.

Table 1.

Evaluation of Simulation Programs

Properties compared	SIMEX	XVR	3D Flood Simulation	Virtual Battlespace
Scenario editor	YES	YES	NO	YES
Communication Possibilities	YES	NO	NO	NO

Technological education for crisis management staff	YES	YES	YES	YES
Terrain database	YES	NO	NO	YES
Possibilities of the import of map background	YES	NO	NO	NO
Practical training of the teams	YES	YES	NO	YES
Recording exercises	YES	NO	NO	NO
Automated result evaluation	NO	NO	NO	NO
Usability for the crisis staff training	YES	YES	YES	WITH MODIFICATIONS
The order of the overall evaluation	**1.**	**2.**	**3.**	**4.**

Source: Own work

CONCLUSION

The causes of power outage cannot be completely eliminated. Whether natural or man-made emergency situation, it is necessary for crisis management staff to be ready to deal with these disasters. Institutions and crisis management authorities should use simulation tools to test skills and knowledge. The article presents the results of the education and exercises carried out as a part of the preparedness for emergency situation and crisis situation. The research has shown that the tested simulation tools are suitable for education and practical training provision, however, the SIMEX simulator, with its utility properties; best meets the requirements for a comprehensive tool.

In the real exercise of the critical infrastructure components, it is possible to allocate the exercising crisis staffs by members of various components. This enables all participants to co-ordinate the individual procedures of each component, the processes of passing information about activities and work standards, and last but not least, to meet and establish relationships before the real emergency situation and crisis situation intervention.

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