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Simulations and their Use in Verification of Preparedness

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Preparedness hold a key role in mitigating the negative effects not only of events with impacts on human health and life, as well as all other protecting interests in the Czech Republic. The primary objective of preparedness is to reduce the humanitarian, social, economic and environmental impacts of emergencies on affected populations and to help them recover and resume ordinary life as quickly and effectively as possible. The preparedness of a territorial unit is an important and necessary part of the sustainable development of society. The development of human society creates opportunities to prevent specific types of danger. Many tools can be used to ensure and verify preparedness in the area for negative consequences, such as tactical or screening exercises. The new trend for verifying preparedness is the use of simulations. The article points out the results of the SWOT analysis on the use of simulation as a suitable tool for verifying the preparedness of the territory. The SWOT analysis includes a financial analysis of the costs and benefits of simulation in the verification of preparedness at VSB-Technical University of Ostrava, Faculty of Safety Engineering, Centre of Simulation Technologies.

1. Introduction

Safety and its associated engineering approaches are inflected in almost every human activity today. To ensure the environment, it is important to monitor and maintain a safe pace with the development of not only new technologies but also approaches. It is a well - known fact that safety is no longer just a matter of technical fields, but its range of solutions has expanded to the socio - political level. Today we can find the concept of safety in relation to the military, economics, ecology, sociology, political science, etc. The concept of preparedness has come to the subconscious in connection with safety in the last 20 years. Preparedness can be connected by several scientific disciplines, but for the purposes of the work it will be prepared related to specific state administration authorities and territorial self-governing units.

The preparedness of the territorial unit to deal with extraordinary events (hereinafter EE) or crisis situations (hereinafter CS) consists of a whole range of partial elements of the safety components of the territorial unit. Each element needs to be evaluated in terms of emergency preparedness separately and then compiled in the overall preparedness of the area. Preparedness is defined as a set of measures designed to mitigate the consequences of an emergency, resp. crisis situations. The measures serve to monitor the occurrence of EE and subsequently to warn the population, to ensure the resilience of the rescue system, to stabilize the situation in the area and to create preconditions for the restoration of basic functions in the area. The current legislation in the Czech Republic does not address the specific concept of preparedness or how to determine the level of preparedness and how to verify it. (SIMPROKIM, 2015)

The article describes possible ways of verifying the level of preparedness of a territorial unit for an emergency. Part of the article is to point out a suitable tool for verifying the level of preparedness, simulation. The possibility of a suitable simulation tool in verification of preparedness is evidenced by SWOT analysis and financial analysis of costs and benefits of simulation in verification of preparedness. The simulations are used in the preparation of exercises for persons included in crisis staffs, which takes place in the premises of the branch of the Center for Simulation Technologies at the Faculty of Safety Engineering, VŠB-TUO.

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1.1 Methods for verifying the level of preparedness

An analysis of the current approaches to determining the approaches to determining the level of preparedness of the territorial system in the Czech Republic has shown that this issue is not comprehensively addressed. Currently, the following methods can be used:

- Monitoring development trends in EE statistics,
- Inspection activity,
- Verification exercises,
- Checklist,
- Stress tests,
- Mathematical modeling,
- Simulation.

Monitoring trends is often used to obtain information on the situation in territorial systems. The system is based on the registration of selected indicators related to EE in the area and their monitoring of the multi-year trend. Depending on long-term trends, the level of preparedness of the area in the monitored area can then be derived. The basic data that are monitored is the total number of EE of the species (naturogenic, anthropogenic), the number of people killed and injured, animals (eg pigs, poultry, cattle), direct damage to property and the environment. Monitoring of indirect damages, eg production outages, the time of treatment of the injured is rather an exception. Simple mathematical procedures are used to determine the trend. In practice, this means that assessments of the level of preparedness of the territorial system of the presented approach have a limited informative capacity, ie. If the occurrence of EE and their losses is on the rise, it can be assumed that there is something wrong with preparedness. (Adamec, 2008)
According to the Crisis Management Act (Law 240/2000 Coll.), the Regional Fire and Rescue Brigades carry out **inspection activities**. In practice, this is more of a methodological aid, where in a controlled checklist the inspection body finds out at municipality, municipality with extended authority, the regional office and legal and entrepreneurial persons fulfilling their obligations engaged in the performance of their duties. By training any subject, we reach a certain level of preparedness. The result of the preparedness check is linked to the administrative evaluation of the statistics. The quality of inspection results often depends on the auditor's ability. It can therefore be stated that this method of verification of preparedness has limited possibilities. (Adamec, 2008)
The verification exercise is an operational-technical tool for verifying preparedness. Verification of preparedness is based on the implementation of a practical check and its evaluation. There is a similar exercise procedure in verifying crisis preparedness. (Law 239/2000 Coll.). The operation of one or more management levels (tactical, operational, strategic) or the operation of one or more components of the integrated rescue system may be subject to verification. All this can be examined at one or more levels of governance. During the preparation of the exercise, goals and tasks are set, which will be verified. The fulfillment of the exercise objectives, the method of implementation of the exercise topic, the functioning of individual components of the integrated rescue system, time information about its course, etc. are assessed. The verification exercise as a tool for verification of preparedness cannot be used for comprehensive verification. (Adamec, 2008)
The checklist method can be used to determine the level of preparedness of both the functional model and the process model. For the application of the checklist, there is a proposal of areas of interest that are applied to verify the level of preparedness of the territorial system. The checklist for the application of the functional model focuses on specific areas - human factor, material resources, services, finance, information, infrastructure and territory. By creating questions for each of the areas, it can offer a comprehensive overview of the preparedness of the territorial system. To use the process model in determining the level of preparedness, a set of indicators was chosen to assess the territorial system's ability to recognize the possibility of EE, prevent preventive measures and their occurrence, mitigate the impact of EE by strengthening the territory, maintain the ability of human, material and other resources and conditions for the restoration of the affected area. The proposal to use the checklist was an attempt to make the assessment of preparedness available up to the level of municipalities. Municipalities sometimes lack enough experts and this is a possible means of determining the level of preparedness. (Adamec, 2008)
The performance of **stress tests** is currently becoming a frequent testing procedure in various areas of safety - safety of nuclear power plants, cyber safety, safety of the banking sector. It is therefore a question of how such a mechanism can be implemented within the process of verification and evaluation of the crisis preparedness of territorial units, resp. their component. An audit can be considered as one of the methods for implementing a stress test. It is a procedure that investigates whether the processes, requirements and guidelines in the organization/system meet the required standards. Such an investigative process often takes place within quality management. Audits are performed for these needs by specially trained auditors. (Adamec et al., 2017)

Mathematical modeling tools can be used to assess preparedness, ie. simplification of reality from a certain point of view (Straškraba, 1985). The model hides positive features, and thus simplifies reality. A good model selects important aspects of reality and covers the insignificant ones, thus helping to think better about reality. The usefulness of the model lies in naming its clear purpose. In practice, a number of types of mental, physical, mathematical and computational models are presented. A suitable mathematical model (descriptive, dynamic) seems to be suitable for measuring preparedness. The static model can be used in the mindset of the data given (eg scheduled cars to deal with the event is some number, however, the real number could be different), the dynamic model addresses the use of the static model, when the dependence on variables over time is implemented (eg changing the number of cars in context over time). (Pánek, 2011)
From the point of view of the perception of safety verification in the area, it is possible to use **simulation** to determine the preparedness of the strategic level. The aim of the simulation is primarily to imitate and pretend. In today's modern computer age, simulations are still evolving and increasingly diverse. Manufacturers are now able to very effectively present a virtual environment based on visual similarities to the real world. The term describe means the division of the examined object into basic aspects, which we can program and impose certain parameters - rules. Simulated, nowadays the concept of virtual can be perceived, reality is based on a simplified description of the real world. Thanks to its simplicity, we can say a more perfect world. When interpreting the results, it is necessary to pay attention to the fact that the modeled world, object or other researched element is ideal rather than real. The simulation creates a connection between education, socio-psychological training and experiential pedagogy. Based on this, new knowledge about the researched object can be gained by experimenting with the object model. The main practical advantage of modeling is the possibility to try and solve problems that do not have an analytical solution, or to verify the properties of expensive equipment before their physical implementation (eg complex integrated circuits, aircraft or atomic bombs). Simulation models are also used as part of simulators or computer games. The simulation output is directly dependent on the input parameters of the specifically created model of the investigated object. The simulation procedure is a repeated run of the created model, setting of input parameters and evaluation of output data. The simulation must be repeated several times to obtain values from which we are able to obtain authoritative results about the behavior of the object under study. (Hrubý, 2018):
Simulation types can be divided (Hrubý, 2018):

- according to the model description used (continuous / discrete / combined, qualitative / quantitative, stochastic (Monte Carlo) / deterministic,
- according to the simulator (on analog / digital computer, physical, real-time simulation, parallel and distributed simulation),
- other (nested simulation (simulation in simulation), reality in the loop, interactive simulation, virtual reality, static/dynamic, educational.

Simulations in the creation of scenarios for persons included in crisis staffs can be used to the verification of the territory preparedness for EE. The premises of a special workplace - the Center for Simulation Technologies (CESIT) at the Faculty of Safety Engineering, VŠB-TUO are used for simulations.

1.2 Use of simulations in the preparation of exercises

CESIT offers facilities for training of persons included in crisis staffs at the level of a municipality with extended authorities or regions, or for training of student crisis staffs. The mathematical model and simulations can be verified according to a pre-prepared scenario used in the crisis staff exercise, or by a permanent working group. The exercise scenario serves the exercise leader as a guide for the implementation of the exercise, for the course and for the evaluation of the exercise. The scenario can contain a timed list of events (eg using a simple tool - Excel), instructions for possible reactions of trainees, a list of activities of the subject in the exercise environment (can be called the surrounding world), an overview of checkpoints for evaluation (course of exercises, activities of individual trainees) and methodological notes for the exercise leader. The results of the simulation lead to a confrontation of the mathematical model with the results of the observations, and this leads to an improvement of the scenario and thus to a verification of preparedness. CESIT can also be used for teaching professional subjects of the department and for the annual international exercises of student crisis staffs FBI / VŠB-TU Ostrava and Instytut Bezpieczeństwa i Zarządzania / Akademia Pomorska Slupsk.
In the past and now, the verification of the set simulation processes and scenarios for solving possible EE takes place in the form of conducting pilot practical exercises for commercial purposes. Among the basic scenarios, real situations such as the Natural Flood in Bohumín, the Flash Flood in Nový Jičín were used (Kavan et al., 2021), or created for the purposes of screening exercises - a traffic accident with a leak of dangerous substances in Kravaře in the Opava region (Pokorný et al., 2016)

2. SWOT analysis for the use of simulation for preparedness verification

SWOT analysis was used to determine the use of the simulation for verification. This is a display using a matrix that shows the basic links between the various elements (strengths, weaknesses, opportunities, threats) on the basis of which potential identification strategies for further development can be directly generated if the simulation is used to verify the area's crisis preparedness. The SWOT analysis assesses external and internal influences in relation to the pros and cons. Based on the results, it is possible to adjust and gradually specify strategic decisions, ie. formulate specific goals and tasks for fulfillment using simulations. The described procedure for the implementation of each step of the SWOT analysis is only indicative and is based on proven practical experience in the implementation of exercises of persons included in crisis staffs and then empirical experience from professional practice. Due to the fact that the method does not have a solid methodological framework, it is possible to adjust the proposed procedure of use according to needs. To use the summary of individual values in the area, the same weights were used in their evaluation. (Brumar et al. 2018)
The individual areas and their points are marked in Table 1.

Table 1: SWOT analysis for used simulate

	Strengths (13)	Weaknesses (- 6)
Internal environment	• Use of the CESIT workplace (non-payment of rent) • Possibility to choose real situations to measure (floods, Blackout) • Possibility to change of the exercise • Ability to create psychological pressure on the trainee • Possibility to involve more participants • Possibility of international exercises • Involvement of participants with minimal knowledge and experts from practice. • Possibility to stop and step the simulation process, repeat selected situations • Changing the roles of exercise participants • Setting multiple possible goals • Smaller time allowance for exercise preparation • Smaller time allowance for the implementation of exercises • Variability in the number of participants	• The need for initial investment to create and maintain technical equipment • The need to collect detailed information about events and their solutions • The need for an IT specialist and an external consultant for start-up and simulation • Time-consuming scenario building • Demanding time for simulation • Entry staff requirements
	Opportunities (6)	Threaths (- 4)
External environment	• High variability of real events • Experts from practice involved in creating the simulation scenario • Use of case studies of real significant events • Demand for exercises using simulation • Increasing the possibility of available IT software tools • Multiple use of the same simulation scenarios for different trainees, users and territories	• Reluctance from practice to cooperate on simulation scenarios • Non-existent procedure for creating simulations for the work of crisis staffs • Insufficient data connection. • Reluctance of trainees to work with new technologies for simulations

Table 1 shows that the S-O strategy was identified, ie the use of strengths in the creation of exercises using simulation and connection with opportunities that are offered from the external environment (external entities, practice).

3. Cost Benefit analysis for the use of simulation for preparedness verification

For financial evaluation, the use of the simulation method as a verification of the preparedness of the territorial unit appears to be the optimal method of Cost Benefit Analysis (hereinafter CBA). CBA is different from purely financial analysis. Its advantage is the effort to include in the final calculation also the social value of impacts, for which their monetary value is not directly obvious or is difficult to determine. In order to be able to financially express all potential costs and benefits, it is necessary to carefully define all beneficiaries who will be affected by the preparedness verification, to varying degrees. For the CBA, we therefore define the target population, i.e. the entities that are targeted by the territorial preparedness verification, and the affected population, i.e. the

entities that will be affected by the territorial preparedness verification, both on the cost and benefit side. In our case, the preparedness of the territorial unit is verified by the simulation method, and therefore the costs and benefits will be related to it. (Renda et al., 2014)
The basic beneficiaries of the target population include (Renda et al., 2014):

- Direct participants in the exercise, i.e. representatives of state and local government, companies,
- Faculty of Safety Engineering, resp. Centre of Simulation Technologies,
- Simulation creators, experts involved in creating scenarios, IT experts

Beneficiaries from the level of the affected population include (Renda et al., 2014):

- Management of the territorial self-governing unit, companies whose employees participated in the preparedness verification simulation,
- Citizens of the territory, company employees, business entities operating in the territory.

Within the CBA, we monitor the impacts of the preparedness of the territorial unit assessed through the simulation method, i.e. costs and benefits for individual groups of beneficiaries. In this particular case, it is the impact on the health and quality of life of the population, on the earnings of the population, on the environment, on the business environment, on the level of education of the population, on civil society, on safety.
Ideally, all impacts are monetized so that we can easily compare them. (Renda et al., 2014)
The following costs and benefits can be defined for the case of evaluating the use of simulation as a verification of the preparedness of the area:
Costs

- associated with the operation of the CESIT,
- investment in technical equipment, including its renewal,
- personal - experts for creating scenarios, IT, administration,
- associated with the collection of data on emergencies,
- participants in the exercise (travel costs, travel allowances).

Benefits

- higher efficiency than the classic form of training in the form of lectures and presentations,
- one scenario can be variably used for more groups of trainers, for different types of territories, different companies,
- with a small variation, the scenarios can be used even after a longer period, i.e. the costs are not constant in the individual years examined,
- the costs are lower when processing the scenario according to the real EE,
- an assessment of the very preparedness of the area, which will be reflected in increased security,
- To show the final overall impact, the CBA results are expressed in two ways:
- Net Present Value, i.e. the difference between the total monetized costs and the total monetized benefits of the measure, discounted to the present value.
- Benefits to Costs Ratio, i.e. the ratio of total benefits to total costs.

However, in the event that we are unable to monetize all impacts, the CBA also includes a verbal commentary, which deals with the assessment of non-monetized impacts. In a situation where we are dealing with safety measures, the CBA result may not always be clearly financially advantageous for recommending its implementation. Territorial safety and preparedness, territorial prevention are typical examples where measures can be implemented, even if the Net Present Value and Benefits to Costs Ratio are negative. (Renda et al., 2014)

4. Conclusions

Preparedness for dealing with emergencies and crisis situations is an important act in the field of civil protection and crisis management. Part of the preparedness for dealing with emergencies and crisis situations is the assessment of risks in the area. The basis of activities to increase preparedness is to answer questions about what types of emergencies and crisis situations need to be prepared, what types of dangers exist in a given area and how great the risk is. In this context, risk assessment is a starting point and a basic and very important input into the process of emergency planning and crisis management, which aims to ensure emergency preparedness and sustainable development of the territory.
The article describes possible ways of verifying the level of preparedness of a territorial unit for an emergency. These are possible tools that are characterized by their simplicity or complexity of use. The importance of using an appropriate tool is declared by the aim of using the tool to verify the preparedness of the area for emergencies. Part of the article is to point out a suitable tool for verifying the level of preparedness, simulation and its division. The results of the use of simulation in the verification of preparedness are documented by SWOT analysis and financial analysis of the costs and benefits of simulation in the verification of preparedness. The simulations are used in the preparation of exercises for persons assigned to crisis staffs, which takes place in the premises of the Center for Simulation Technologies at the Faculty of Safety Engineering, VŠB-TUO or outdoors in the case of a use commercial scenario for real crisis staff of a municipality or region.

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