Enhancing the quality of contingency planning by simulation

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ABSTRACT

Contingency planning is a significant challenge when dealing with rarely occurring cases. First of all, the situation related threats can be difficult to identify. Moreover, it is difficult to conclude what happens when multiple threats occur simultaneously. In this paper we introduce the idea of an application which allows seamless cooperation between many experts.

In this paper we describe a computer based simulation application which is designed to support contingency planning – having resources available – in extreme winter condition. First we introduce the background of the simulation - sparsely populated areas in Northern Finland where long distances and extremely cold weather can make disturbance situations even more difficult to be normalized by authorities. Secondly we present the tools that are used to build up the application. Finally, we discuss what benefits the application offers for the authorities, preparedness planning and society.

Keywords

Contingency planning, multi-authority situation, power outage, rural areas, simulation

INTRODUCTION

In Finland, the highest political authority responsible for internal security has recently emphasized the importance of preparing for large-scale accidents in advance by designing measures and joint exercises. In particular, the challenges in sparsely populated areas have been highlighted (Minister of the Interior, 2014).

Recently, an exercise (VALVE-2014 disturbance exercise) took place in Finland that was aimed at restoring the electricity supply after a power failure. The exercise had to be discontinued when it was found out that restoring of electricity was much more difficult than anticipated. Thus, it can be assumed that a recovery from a real disorder may take a longer duration than expected and therefore, it poses a serious threat to society.

This paper will introduce a computer simulation based application which is designed to support contingency planning for extreme winter conditions. The main focus of the developed application is on simulating the impacts of a large scale electricity breakdown. As a starting point for the simulation, a crisis scenario has been sketched. According to the scenario an extreme winter storm and low temperature affects the Barents region causing the electricity consumption to increase within the whole area. This will lead to an electricity overload and consequently severe power outages take place. Moreover, the area of Lapland gets only 20% of the normally available capacity of electricity, and the authorities need to decide which areas are prioritized The objective of the application is to identify the most vulnerable population in the timeframe of 72 hours.

The affected area is characterized by long distances, aging population in sparsely populated areas, their ability to live a longer periods of time under abnormal circumstances, the scarcity of resources that are planned for the normal conditions, and the additional load formed by tourist centers like ski resorts.

Cold weather (below -30°C) occurs each year in Northern Finland. At the end of January 1999 the temperature was between -45°C and -50 °C for approximately a week in northern and central Lapland. Finland's coldest measurement of -51.5 °C attained Kittilä, Pokka 28.01.1999 (FMI, 2014). Using the maximum likelihood estimation method it can be expected that even -44.9 °C is possible once every 50 years, and -46 °C is possible once every 100 years in this affected area.

Power supply can be affected by a variety of reasons. Finland imports electricity from Russia, Sweden and Norway. If the import of electricity is prevented or serious disturbances arise from problems in domestic production, the electricity consumption can be significantly higher than the production. In that case, the consumption of electricity has to be rationed. In rural areas, the main way of heating is direct electric heating but fireplaces, stoves, or other wood heating methods are also used - usually to support the main heating system.

The concrete goal of the application is to help the authorities to prioritize the allocation of critical resources which are in shortage. The application aims to identify areas which require urgent actions, e.g. evacuation. In the simulation power outage causes rapid decrease of indoor temperature of the residential buildings so that safe and secure living conditions are endangered.

In this application, society and its functions are described in general terms. Precise details of efforts have been omitted. The affected area is divided into 1 * 1 km sized geographical areas, geo-cells. In each geo-cell the number and location of residential buildings, the inhabitants as well their age distribution are known. Furthermore, estimated thermal insulation capability of the buildings in the geo-cells has been derived from the construction year.

As the requirements for thermal insulation of houses have been increased year after year, the ability to retain housing conditions is best described by their age.

TOOLS

In this paper we will present the tools that are used to build up the application: Agent-Based Simulation Model (ABSM), VTT House, Insta Response Preparedness Planner and CRISECON tools. The application is based on developed integration framework that enables the integration of separate simulation tools.

Framework of this simulation constitutes the platform that can be used to bring together a variety of building blocks and supporting tools. Some of calculation models are combined with ABSM into a single user application in this simulation. In this paper we introduce a few of these calculation models. VTT House is a computing model that describes a realistic way to cool buildings in various weather conditions. Insta Response Preparedness Planner allows user to create different response models for disturbance situations and to simulate their behaviour. Finally CRISECON is used to produce the information about the economic impacts in each simulation.

These tools are using a common base that has been formed from object of interests (OOI), world states (WS) and repository (OOI-WSR). OOI is an entity (object) that is manipulated by the user or automatically by some mathematical models. WS represent a meaningful OOI data snapshot at specific time and holds list of OOI instances with state that is relevant to specific point in time. OOI-WSR is a repository that enables archiving, querying and manipulation of OOI world state data. (CRISMA 2014c)

The application architecture is sketched below in Figure 1.

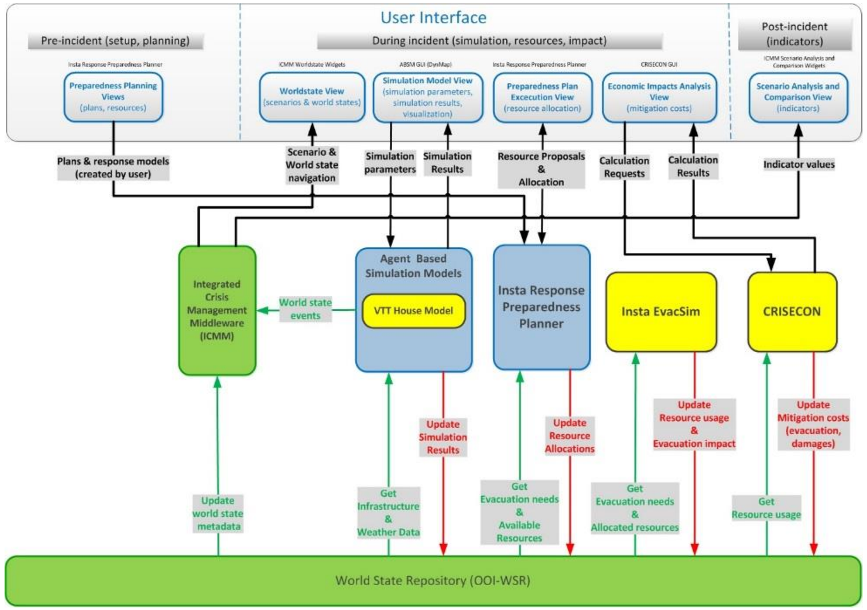

Figure 1. Architecture of the simulation application

ABSM - Integrating the Simulation Models

In the application ABSM is used for simulating the evolution of crisis within environmental, and spatio-temporal constraints that are given by the operator.

The application and the model allow the user to monitor and control the state of different resources (OOIs) in conditions where power grid outage initiated cooling of buildings in a chosen area of interest. In this simulation it is done by Resource Management Model, built upon the generic OOI concept with a context dependent behavioral pattern specially developed for this simulation crisis domain.

The ABSM may use several application-specific sub-models. The Life condition index, calculated for each geo-cell, serves as a good example. Additionally, the model has capabilities to use external stand-alone models, describing the effects of environmental conditions on building-type OOIs.

The model can collaborate with different applications focused on resource management, but only implicitly linked to the ABMS simulations – like Insta Preparedness Planner and CRISECON, changing information over common data repository (OOI-WSR) and driven by a common GUI.

Environmental effects and status of the power grid (on/off) are controlled and monitored at geo-cell level. The simulation plays with the summary effects of the environment -meteorological conditions and power supply - on groups of Buildings and Habitants in these buildings. The ABSM calculates “Life Condition Index” for each geo-cell, based on the cooling-situation of the buildings and habitants’ category in “critical buildings”. The end-user can follow the situation at a geo-cell level for the selected area of crisis - a set of numbered geo-cells - and the simulation results are recorded in OOI-WSR and visualized by GUI.

The Operator defines an initial World State WS0 - or alternatively from some intermediate state WSx - up to WSn, writes it into OOI-WSR and launches the simulation for a defined number of time-steps. The ABSM reads the initial World State WS0 from OOI-WSR and records all consecutive World States into OOI-WSR up to the end of the experiment. Optionally, the simulation can be terminated and restarted at any time by an external command

VTT House – Cooling of Houses

VTT House is a simulation model for calculating the extreme cold weather based cooling curves of different types of buildings (CRISMA 2014a). In this application, VTT House is used to simulate the cooling of residential buildings due to a large scale power outage (Molarius, Tuomaala, Piira, Räikkönen, Aubrecht, Polese, Zuccaro, Pilli-Sihvola and Rannat, 2014). For this purpose, three different building types (light one family house, medium apartment building, and heavy apartment building) are chosen to represent the most typical residential buildings in the affected area. The classification of buildings is based on the different heat insulation capabilities. These capabilities have been derived from the Finnish Population Information System (FPIS) which is a national register containing the basic characteristics of the buildings, including e.g. location coordinates, gross floor area, number of stores, heating systems, year of construction, etc.

As a result of the simulation, the model calculates hourly-based inside temperatures of the selected building types [°C]. In addition, the model offers time series data including e.g. date and time, used outside temperature [°C], used diffuse solar horizontal radiation [W/m2] and used direct solar horizontal radiation [W/m2]. The model can also be used to predict the speed of temperature recovery when heating is restored.

The model is based on EN ISO 13790 and EN 15241 standards in addition to models for estimating solar radiation. The model includes methods for the dynamic hourly-based calculation of building energy and thermal performance, including heating and cooling and airflow related energy losses due to the ventilation system and infiltration. In the application VTT House is implemented as a SOAP-based web service (CRISMA 2014a).

Insta Response Preparedness Planner – Resource Allocation Proposals

Insta Response Preparedness Planner is a decision support tool intended for contingency and preparedness planning for authorities, operators of critical infrastructure, large organizations and industry, for example. It enables user to create plans for wide range of emergencies and threats identified in risk analysis process. When executing a plan, the tool provides pre-defined suggestions for mitigation actions and communications as well as resource allocation proposals for the situation described by the user. The resource data can be managed internally within the tool or alternatively the tool can get the resource data from an external data repository. Insta Response Preparedness Planner can also connect to external simulation models to enhance the planning process and to validate the created plans.

In application, the focus on the usage of Insta Response Preparedness Planner is on providing resource allocation proposals. The simulation is modelled using different simulation tools and the situation data is stored in common data repository (OOI-WSR) which also acts as a communication channel between different tools of the application. Insta Response Preparedness Planner gets the situation data in different phases from the repository, complete with the need for mitigation capabilities. The need can be, for example, a capability to evacuate 152 people from a certain geographical area due to the cooling of residential buildings causing a risk of injuries or death to the most vulnerable groups of people. Based on this need, Insta Response Preparedness Planner proposes evacuation resources (transportation, accommodation) to be allocated. User selects one of the proposals and the tool sets the resources to be allocated. As the situation evolves, the impact of this mitigation action is modelled with the Evacuation Simulation tool.

EvacSim – Simulation of Evacuation Progress

EvacSim is a simple simulation model, which calculates the impact of resources allocated to evacuate the people. The model gets the capabilities of the allocated resources from the common data repository (OOI-WSR), estimates the roundtrip time between the location of the resource and the target area and calculates how many persons can be evacuated within given period of time.

CRISECON – Calculation of Costs

CRISECON is an economic impacts evaluation tool that has been developed to support crisis management related decision-making (Räikkönen, Pilli-Sihvola, Kunttu, Yliaho, Jähi, Zuccaro and Del Cogliano, 2014). The intended usage of CRISECON is twofold: Firstly, it can be used to present the economic impacts arising from crises by taking into account different damage costs. For example crisis impacts on people, infrastructure, nature, agriculture, and other assets. Also, the costs of rescue and emergency operations can be included. Secondly, CRISECON can be used to assess different mitigation proposals and their costs and benefits. In that case, investment costs and operating costs of the mitigation measures need to be taken into consideration as well as the risk reduction generated by the measures.

In this simulation case CRISECON is used to produce economic indicators from different scenarios. Thus, the aim is to enable the end-users to compare the simulated scenarios from the economic point of view. The emphasis is on evaluating emergency and rescue costs as well as damage costs. Regarding the emergency and rescue costs the main focus is on evacuation costs relating to transportation and the temporary sheltering of evacuated people. The damage costs are mainly caused by frozen water pipes in the cold buildings. To evaluate the total costs of the scenarios, simulation results on the usage of evacuation resources and the number of frozen buildings is used as input data. Moreover, to calculate the results, the user will have to give at least the rough estimates of the unit prices for the allocated resources and the building damages.

In application CRISECON is implemented by two software components: CRISECON GUI and CRISECON service (CRISMA 2014b). CRISECON GUI is a user interaction component and provides a graphical user interface (GUI) for the end users. CRISECON Service is a federated calculation and simulation model (WPS Service API) providing a service to calculate the costs of the selected scenarios.

CONCLUSION

In this paper we have introduced a simulation based application that is developed to give support to authorities in contingency planning. Typically the goal of contingency planning is to identify unlikely threats and to draw up procedures to minimize their effects. In the context of an extreme winter condition scenario described in this paper, the application would help users to create alternative scenarios, to locate the most vulnerable areas, to identify different resource allocation options, and to calculate the costs of different scenarios.

The comprehensive identification of threats requires that wide range of authorities and other actors are involved in the process. Even though authorities have had their own models for different purposes, there haven't been any tools available that would enable the integration of these models. With the help of the developed application these separate models can be integrated into a single application. This could help to improve contingency planning as it opens up new ways for inter-authority planning as well as stakeholder cooperation. Ultimately this should improve the safety of the population and the society.

Moreover, the scope of application could also be expanded by adding new simulation models. For example, household services for the elderly, water and waste water services, road blockages (either because of the weather conditions or traffic accidents or even both), and communication traffic blockages, could all be taken into account with applicable models. As an advantage, data for these kind of new tools would somewhat occur already.

ACKNOWLEDGMENTS

The work in this paper has been done in CRISMA (Modelling crisis management for improved action and preparedness) project. The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 284552. More information from the project, please go to www.crismaproject.eu/.

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