Coordination of Processes as a Starting Point for Simulation-based Management of Biological Incidents

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Abstract: Biological incidents nowadays represent more often as well as more serious threat endangering important assets. Their management requires complex approach including high demands on technological support. This paper neither contributes with another simulation model or results, nor offers the application of specific technology. It utilises the literature analysis and interviews with experts to reveal the framework for potential options and scenarios for simulation employment in the realm of management of biological incidents. Conceptual issues related to the simulation of biological incidents together with process perspective are provided and advantages as well as prospective utilisation in modelling and simulation are discussed.

1 INTRODUCTION AND PROBLEM FORMULATION

Biological incidents can be defined as events when a biological agent harms or threatens humans, livestock or other important assets (UNODA, 2009). These problems represent a topical issue in several areas of our society regardless if these are caused by the biological weapons or if they occur unintentionally like the leakage of a dangerous substance from a factory or laboratory, or natural incidence of a disease. Whereas the former can be considered as more perilous, the latter is usually more easily manageable. It is especially because focal points can be typically identified quickly and localised more precisely. Therefore, the critical assets can be recognised faster and adequately protected. On the other hand, during these incidents it is hard to react promptly in the initial phase, because the first phase of the agent identification can last a significant time. Nevertheless, if appropriately managed, their consequences can be minimized (Bureš et al., 2012b). Coping with a biological incident involving a highly persistent agent (e.g. anthrax, Brucella, influenza or zoonosis) is a complex process. It requires extensive information and both considerable and appropriate resources. Unfortunately, these are likely to be limited, particularly if multiple facilities, areas or groups of people are affected (Krauter et al., 2011). Therefore, any available tool for decision support and for the improvement of the effectiveness of the course of action should be employed. This paper firstly introduces the current state-of-the-art related to the modelling and simulation utilisation during the process of biological incidents. Afterwards, methods followed by results are discussed. Finally, the limitations, further research perspectives and implications of the mentioned research are provided.

2 SIMULATION AS A RESEARCH METHOD

As discussed above, the biological incident management should be supported by appropriate and efficient tools. Therefore, this paper addresses these issues employing the simulations. The idea to use modelling and simulations in epidemiology has been mentioned earlier (Hurd and Kaneene, 1993). Nevertheless, only particular aspects of the complex problem predominantly attract researchers' attention. For instance, several models such as susceptible-infected (SI) model (Naji and Mustafa, 2012),

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susceptible-infected-recovered (SIR) model (Yusuf and Benyah, 2012), or susceptible-exposed-infected-recovered (SEIR) model (Forgoston et al., 2009) have been already developed. Peculiar feature to simulation in this realm is the examination of characteristics and behaviour of a particular system on the basis of the experiments realised on the mathematical model of this system. Commonly used approaches are based on a Liapunov function (Gao et al., 2013), LaSalle's invariance principle (Xu, 2012), or Bayesian Markov-chain-Monte-Carlo inference (Filipe et al., 2012). All the aforementioned models and tools are proved to be meaningful and applicable. However, their utilisation is not mostly related to the general context. Usually, every prospective user selects a situation or aspect in which various systems, tools, or methods are applied (e.g. prehospital care (Junker, 2007) or industrial and agriculture incidents (Bureš et al., 2012a)), but without broader perspective, although a few of frameworks or methodologies have been developed and published (Nakano et al., 2009; Otčenášková et al., 2011).

Apparently, the successful application of simulation requires a lot of precedent work prior to building a computer simulation model. The simulation itself consists of eight major phases, which need to be followed for the proper application of the simulation methodology (Ülgen et al., 1994). Rarely authors do present in their studies the context and evidence their awareness of the overall simulation process. Mostly, the simulation models are described and results are interpreted. Therefore, the aim of this paper is to introduce a model of the epidemiological treatment of a biological incident that comprise all stages of the process from incident occurrence to its final termination. This process view can be successfully applied as a framework for simulations of biological incidents, which would be more complex, respect the whole process, and include more stakeholders.

3 METHODOLOGY

The main research question which determined the research direction and methods was the following "Is there a general process that can serve as a framework for several existing and prospective simulations in the area of biological incidents?". Thus, the discussed research activities were grounded on the literature review and quantitative research. The former was based on the analysis of information resources such as military documents (McClellan et al., 2010), public institution tools (NASA, 2010), and approaches incorporated in procedures of public health institutions. These include for example State Veterinary Administration of the Czech Republic, The National Institute of Public Health in the Czech Republic, or The National Reference Laboratory of the Czech Republic. The latter consisted of several iterations of in-depth un- and semi-structured interviews with experts in epidemiology and public health realm. The knowledge revelation, extraction and further compilation were employed.

4 RESULTS

Three schematic process models of biological incidents were developed. Based on the consultation and recommendation of experts, the selected case studies were anthrax, influenza and diarrhoea. The complex process from its beginning representing by the symptoms occurrence to its termination was modelled. Whereas the full version of the process description identifies several tasks, steps, stakeholders or utilisable tools, the Appendix of this paper comprises the simplified description (due to space limitations) of the overall process of dealing with the influenza epidemics. Particular model elements can be consequently analysed and appropriate technology can be deployed. Not only decision support technologies or methods, professional databases and communication tools can be used, but also simulations of different biological or epidemiological aspects can be applied.

4.1 Implications for Epidemiological Simulations

Typically, simulation models are utilised during the Scenario development phase (as stated in the introduction section). Considering the context of the scheme in the Appendix, it is obvious that various parts of the incident can be simulated. The most advantageous is to monitor the consequences of diverse actions during relevant phase of the incident. The process indicates that it can be also put in use in Application of anti-epidemic measures or Anamnesis trace stages. At the beginning, there are three options how an incident might occur. The simulation would provide for example the comparison of time needed for the whole incident termination based on differences among the situations. For instance, there is a significant difference between two cases. The first one is when the infection is diagnosed at the general practitioner. This might be compared to the problem on a particular plane with an infected person. In this situation, all other people who were on the board and are suspected from the infection have to be traced and their condition has to be monitored. During this phase, the multi-agent based modelling of the agent spread with integrated geographic information system can be helpful (Wang et al., 2010; Laskowski et al., 2011). The duration of the initial phases of the incident depends also on the methods employed in the laboratory to analyse the samples. The three basic methods demonstrate various demands on people, equipment, necessity of safety precautions or time for further actions. Methods potentially employed with their characteristics follow:

- prompt methods: identification if it is influenza virus or not,
- Polymerase Chain Reaction (PCR) method: identification of influenza type,
- virus cultivation: clear specification of the virus type and its analysis considering the purposes of future vaccine preparation.

Demands within Application of anti-epidemic measures in case of serious condition or suspicion of new virus have the same impact on different simulation scenarios. The quarantine simulations might include the following parts:

- isolation (relating to infected people), possibly their treatment,
- quarantine of health people suspected from the infection,
- medical control (health condition monitoring).

Apart from these, closure of hospitals, institutions of social care and places, where susceptible and endangered population is present, is necessary. Mostly, the searching for and contacting of people who were in contact with the affected ones (especially colleagues, co-passengers, family etc.) is realised. There are cases when for example police have to be involved as well to coerce people to stay in the focus of the infection.

Before the virus is specifically described and targeted measures are taken, a lot of information should be gathered dependant on the seriousness of the whole incident. These factors might also influence the overall simulation and therefore should be taken into account. Usually, the following characteristics should be gathered:

- availability of treatment and vaccination,
- threat of the transmission,
- ways of the spread,
- period of infectiousness,
- susceptibility,
- infectiousness,
- or fatality rate.

All the mentioned factors can be considered as variable inputs in the simulations which influence the extent of stakeholders to be involved, time, material, financial and other resources to be utilised and also the overall effectiveness of required processes within the incident management.

4.2 Prospective Users

Furthermore, more stakeholders can be included and simulation results can be more realistic. From the perspective of involved institutions and individuals, especially the awareness about the relations and dependency is supported by the created model as well as by the simulation process which shows who interacts with whom and which processes consequent from the course of action of particular participant. This opens a new perspective for simulation with the help of multi-agent models and techniques, which have already been applied in case of specific instances (Dion et al., 2011; Linard et al., 2009). Each participant might moreover choose the relevant part of simulation which is appropriate for his or her purposes. Such advantageous approach is both effective and clearer to the particular stakeholder. For this reason, participants can try various situations, get more expertise and experience without any threats and costs even before an incident occurs.

4.3 Integration Perspective

The acquired results enable not only putting the existing simulations and models into context, but also focusing future results and efforts on better and meaningful integration of prospective outcomes with other systems and applications. This is feasible due to the practical and verified framework. Moreover, the integration of simulations does not have to remain at the conceptual level. Since the process framework determines the context, issues related to data integration, methodological or application integration can be considered. The final integration can contribute to the general scheme of technological tools utilisable in management of incidents, as described by Otčenášková et al. (2011).

In business practice every process has its own owner who is responsible for its execution and outputs. The process view on biological incidents reveals that this approach ensures that the ownership is distributed. This causes issues related to responsibilities, budgeting or willingness to overcome existing barriers related to the technological automation of particular process segments. Unless this is solved, the simulations will remain mostly isolated isles in the world of technological support of decision-making in the area of biological incidents management.

As apparent from Figure 1, the determination of all parts of the simulation processes and all stakeholders provides with clearer and easier management of necessary actions. Moreover, the end users vary significantly and therefore, the outputs in form of recommendations, decision support, or scenario creation can be prepared with the help of plethora of technologies. At the beginning of the incident management, necessary data must be collected from several resources (see bottom boxes in Figure 1). These are afterwards processes thanks to the employment of techniques and methods including data transformation, database, analytical and end user tools. Simulation belongs to the end users tools and therefore influences significantly the technological support of the incident management and consequently both the chosen measures and actions. Hence, several technologies can be mutually interrelated with computer technologies and provide users with the complex decision support.

Regardless the biological incident, the mentioned concept ensures better resource planning, easier identification of stakeholders, clearer and quicker determination of responsibilities and involved parties resulting in better crucial assets protection followed by future prevention and preparedness improvement.

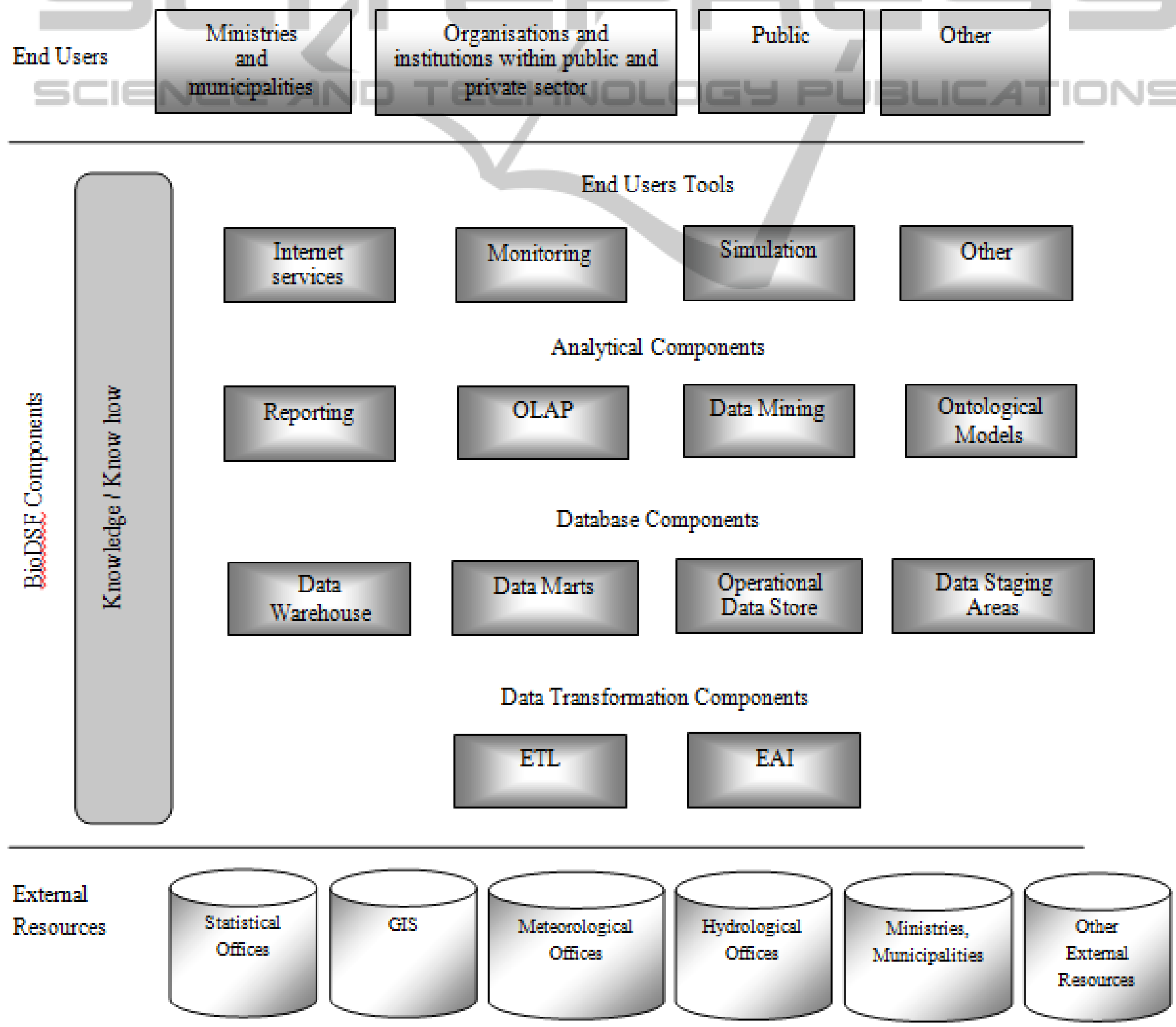

Figure 1: Technological Context of Simulation in the Biological Incident Domain (Bureš, 2012b).

5 LIMITATIONS AND FURTHER RESEARCH

The aforementioned research has particular limitations. Even though, it was developed in the Czech Republic, the applicability within different countries is possible due to the general concepts which are used. Nevertheless, some changes relating to the specific institutions involved or the procedural regulations might be relevant and should be considered. As discussed above, only a few scenarios have been simulated so far. Therefore, the creation of scenarios for the purposes of other diseases, infections and various threats and incidents is possible.

There are various approaches and methods relevant to be considered for the purposes of further research of the discussed concept. These comprise exploration of advanced utilisation and development of gathered information and created models. As examples, the following can be mentioned:

- Markov Chains to monitor the overall system changes and to evaluate the probable transition from one state to another,
- Net Analysis to represent the relations more precisely and comprehensibly,
- Process Analysis to support the understanding of chronological changes of the whole system (model),
- Analysis and Forecasting of Time Series to reach more appropriate system description and to provide more precise predictions of the following development,
- Causal Loop Diagram to visualise the influence of one component on another or
- RASCI Matrix (responsible, accountable, support, consulted and informed management of the particular problem) to determine responsibilities during the processes.

These methods can be either used separately or they can be incorporated within already done outputs to enhance their usability and precision of the simulations and models.

6 CONCLUSIONS

Currently, the biological incidents require attention especially because these occur relatively often, the processes within them demand a lot of resources and their consequences are more dangerous and extensive. Nevertheless, simulation exemplifies a method which can significantly support the processes necessary for successful and prompt incident termination. This paper introduces the process view on incident management which can consequently represent a framework for the computer-based decision-making support. It further highlights the possibilities and the advantages of simulation method during the biological incident management. The overall coordination and various stakeholders are supported and the course of action is managed more effectively to protect valuable assets. The simulation is also contextualised and areas for further research and development of the mentioned concept are discussed.

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APPENDIX

Process View on the Influenza Incident (Authors' Research)