First Steps Towards the Automated Production of Intelligent Incident Cordon Zones: Developing a Conceptual Model of Incident Scene Management

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1 Introduction

The emergency services response to large life-threatening CBRN (Chemical, Biological, Radiological or Nuclear) emergencies, which are mainly associated with terrorist attacks, is a very complex process. It requires the co-operation of a vast amount of people representing several agencies with different sets of priorities. Moreover, very little is known about the actual incident in the first stages of the response. This high level of uncertainty coupled with the fact that the response teams are often formed ad-hoc enormously challenge the management of the response.

Before any decision is made, incident commanders, who manage the incident response, have to ensure that they possess all essential information. In accordance with the Civil Contingencies Act (Civil Contingencies Act, 2005) the emergency responders are obliged to share information with each other. Much of this information is of a geospatial nature. The recent Open Geospatial Consortium Web Services, Phase 4 (OWS-4) interoperability testbed has demonstrated that the standards and technology exist to provide access to multiple sources of real-time geospatial information over the Internet (Open Geospatial Consortium, 2006).

However, essential geospatial information at the right time does not yet guarantee a successful response. This information has to be carefully analysed. Subsequently, crucial decisions about the incident response are made based on those analyses. Several research projects have looked at techniques which can automate part of the decision making process to help support the work of incident commanders (Turoff *et al.*, 2004; Batty *et al.*, 2003; Kitano *et al.*, 1999; de Silva, 2000; van Borkulo *et al.*, 2005). However, to date, there are no formalised nor automated decision making processes which can support the work of the incident commanders in the matter of securing the incident site. This research specifically concentrates on delivering a methodology which provides an enhance solution

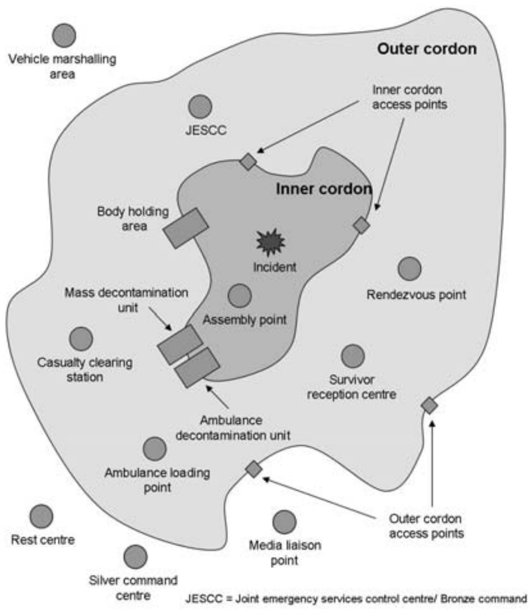


Figure 1: One of the two rich pictures depicting CBRN incident scene management.

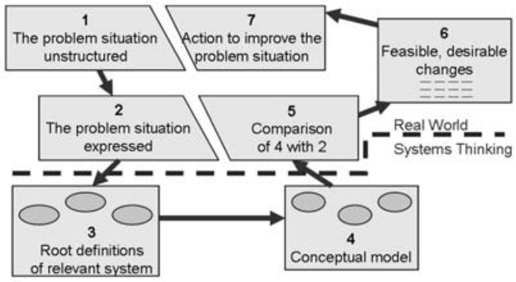
for modelling and optimising size, shape and position of inner and outer cordon zones by developing a tool for the automated demarcation of Intelligent Incident Cordon Zones.

This paper presents the first steps in developing such a tool by identification of management of the incident scene using a rich picture approach (Monk and Howard, 1998). Subsequently, a conceptual model is developed based on that information. This work has been undertaken within a soft systems methodology framework (Checkland and Scholes, 1990).

2 CBRN incident scene management

One of the first decisions incident commanders have to deal with, when managing the response to the large CBRN incidents, is the appropriate demarcation of the affected area into inner and outer cordon zones. Each cordon zone has a distinct function. The inner cordon zone directly secures the incident site and its proximate neighbourhood which is contaminated by the aggressive CBRN agents. The purpose of this cordon is to protect the public and to preserve evidence of the crime for police investigation. People involved in the rescue operations within the inner cordon are allowed to access that area only through designated cordon access point and must be appropriately dressed and equipped.

To support the operations of the emergency services the outer cordon zone is set-up di-



1	Problem Situation	- Basic research into the problem area
2	Rich Picture	- Expressing the problem situation by drawing a diagram
3	Root Definitions	-Selecting the view on the situation from different perspectives -"*Whats*"
4	Conceptual Model (CM)	- What the system must do -"*Hows*"
5	Comparison of CM with Real World	- Comparing step 4 with 2 and identification of their similarities and differences
6	Changes identification	- Identifying feasible and desirable ways of improvement
7	Recommendation of improvement	- Suggestions for implementation of the changes identified in step 6

Figure 2: SSM: conventional seven-stage model (Checkland and Scholes, 1990).

rectly around the inner cordon. The main function of the outer cordon is to provide sufficient space for the location of key off-site functions and facilities. Since the emergence of a CBRN incident is difficult to predict the outer cordon also serves as an additional safety zone which will protect the public if the contamination unexpectedly expands outwards from the incident. Figure 1 depicts core facilities for the inner and outer cordon zones. (HM Government, 2005).

3 Knowledge extraction process

The Civil Contingencies Act (Civil Contingencies Act, 2005) establishes a general framework to assist with selection of suitable locations and extents for both cordon zones. However, the actual decision making process is not a trivial task due to its complexity. Currently, the decisions are based purely on the experience and knowledge of the incident commanders in charge. The decisions are supported by geospatial information about the exposed area, standard operating procedures, information about the dangerous substance involved in the incident and regular reports from the incident site. The decisions are also limited by number of available resources for the actual cordons placement. Since the incident commanders represent different organisations with different concerns over the cordons, the final decision results from several iterations based on timely negotiation of compromises.

Extensive research into the cordon placement problem has to be accomplished before any changes to the current incident scene management system can be suggested. Therefore, a close collaboration with Nottinghamshire Fire and Rescue Services (NFRS) and Nottinghamshire Police (NP) has been established in the initial stages of this research project. Experienced incident commanders have been interviewed to describe the function of the CBRN incident scene management system, responsibilities and priorities of every emergency services. Soft Systems Methodology (SSM) has been used to perform a detailed analysis of complex situations with divergent views about the exact definition of the problem. The rich picture technique has been selected as a tool for capturing and formalising the 'problem situation' in term of extracted knowledge about the current system (Couprie *et al.*, 2006; Wilson, 2001; Checkland and Scholes, 1990).

SSM places emphasis on people's perception of reality, their experience and knowledge of the environment. In general, SSM is divided into seven stages depicted in Figure 2. The stages can be divided into two distinct groups based on the different perceptions of the problem; the real world view and the system thinking view. Each step of the SSM represents an iterative process where every iteration is discussed with people involved in the system (Checkland and Scholes, 1990).

4 Results

4.1 Step 1: Building rich pictures

To capture and organise all possible views of the problem two rich pictures has been compiled from the information that was obtained from the interviews. Since the creation of the inner cordon zone is dependent on different factors to those which influence the location of the outer cordon, two separate rich pictures were drawn to depict the decision processes. To produce the final rich pictures required three iterations. Figure 3 is a rich picture depicting the process of inner cordon zone creation. The rich picture representing the outer cordon zone creation is similar but expresses a number of different concerns. The results of every iteration were discussed with incident commanders.

The picture represents the primary stakeholders in the decision making process. These are the main category one responders as defined under the Civil Contingencies Act (2005) i.e., FRS, Police, Ambulance and Local authorities. Each stakeholder's concerns and desires that are relevant to the CBRN incident scene management system are represented by thought bubbles. Finally, the interrelationships and information flows are expressed by oriented arrows with action labels. Pictorial symbols are used to emphasise the main components involved.

4.2 Step 2: Developing a root definition

The process of establishing an essential perception of the system that is to be modelled involves the construction of a 'root definition'. The root definition provides a succinct encapsulation of the problem from a particular perspective and forms the backbone of the

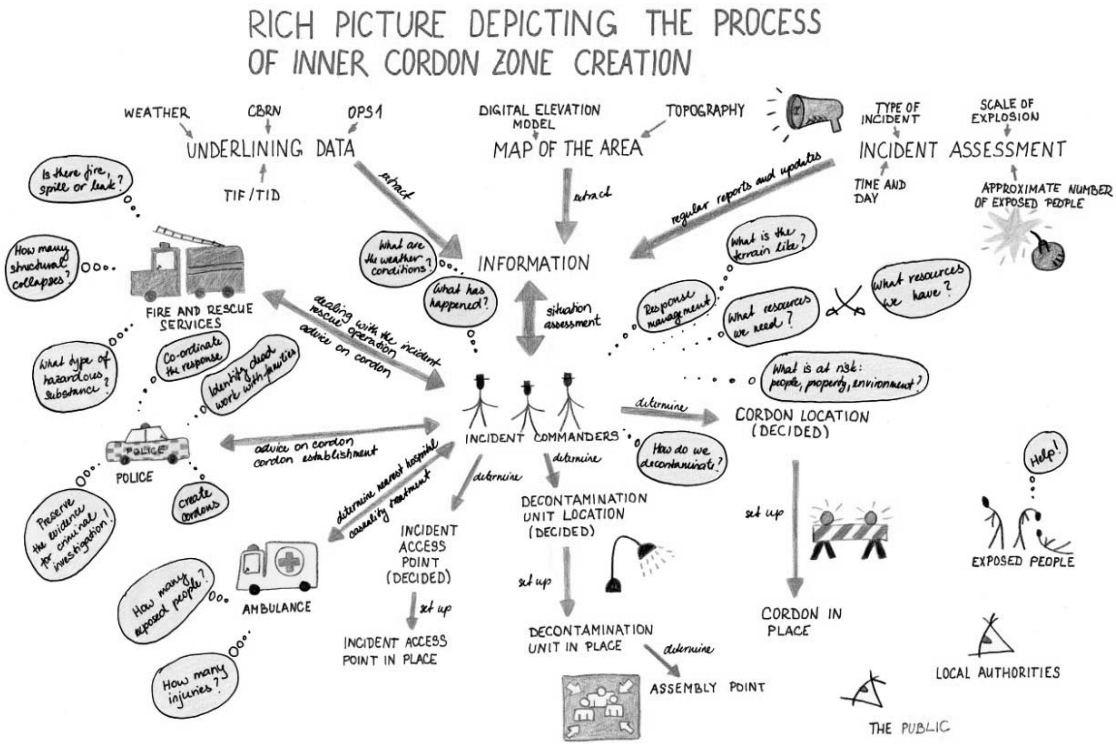


Figure 3: CBRN incident scene management of inner cordon placement.

activity system that is depicted in the rich picture. The core of the root definition is expressed as a transformation process that takes some entity as input, and changes that entity, to produce a new form of that entity as output. The input for the root definition is selected from issues or tasks represented in the rich picture. The actual root definition is written as a sentence of strictly defined structure. Six elements that are summed up in the mnemonic CATWOE were used to check the formulation of a root definition and to question the words that were used within (Wilson, 2001);

C (Customers) - everyone who gain benefits or drawbacks from the system;
A (Actors) - those who would perform the activities defined in the system;
T (Transformation processes) - the conversion of input to output;
W (*Weltanschauung*) - the German expression for world view which makes this transformation process meaningful in context;
O (Owner/s) - those who have proprietary right to start or shut down the system;
E (Environmental constraints) - elements outside the system which it takes as given.

In the CBRN incident scene management system only one root definition is derived based on both pictures: the first one depicting the process of inner and the second one of outer

The CATWOE analysis on the root definition

C	public, victims, first responders, businesses, local authority	
A	personnel involved in the response	
T	cordons required →	cordons placed
W	to protect the public, secure the incident scene, provide working environment for the first responders	
O	incident commanders	
E	the incident, physical environment, infrastructure, resources	

Figure 4: CATWOE analysis of the root definition.

cordon zone creation. Although the processes of creating inner and outer cordon differs, they share the same aim which is to secure the incident scene and protect the public. The final root definition reads:

An incident commanders owned system, operated by incident response officers, to place incident cordon zones, in order to protect the public, treat the victims, secure the incident scene, provide a working environment for the first responders and limit disruption of business activities to a minimum while considering the incident, physical environment, infrastructure and available resources.

The CATWOE elements underlaying the root definition are depicted in Figure 4.

4.3 Step 3: Developing a conceptual model

The general aim of the conceptual model is to capture the essential concepts of the system and to organise initial thoughts and ideas. The modelling process consists of assembling and structuring the minimum necessary activities to carry out the transformation process specified in the root definition (Checkland and Scholes, 1990; Wilson, 2001). The configuration of the model is based upon logical dependencies where the relationships are shown by linking the activities with an arrow directed from the antecedent to the consequent. The creation of the conceptual model is based on three questions related to the transformation where answers to each question may become subsystems of the general system:

What has to be done to acquire the input?
What must then be done to reach the output?
What must then be done to make the output available?

The conceptual model displayed in Figure 5 illustrates all activities of the CBRN incident scene management system which is divided into three subsystems. The first subsystem depicts information acquisition processes. The information about the actual incident is supplemented in form of regularly updated reports from the incident scene. This information

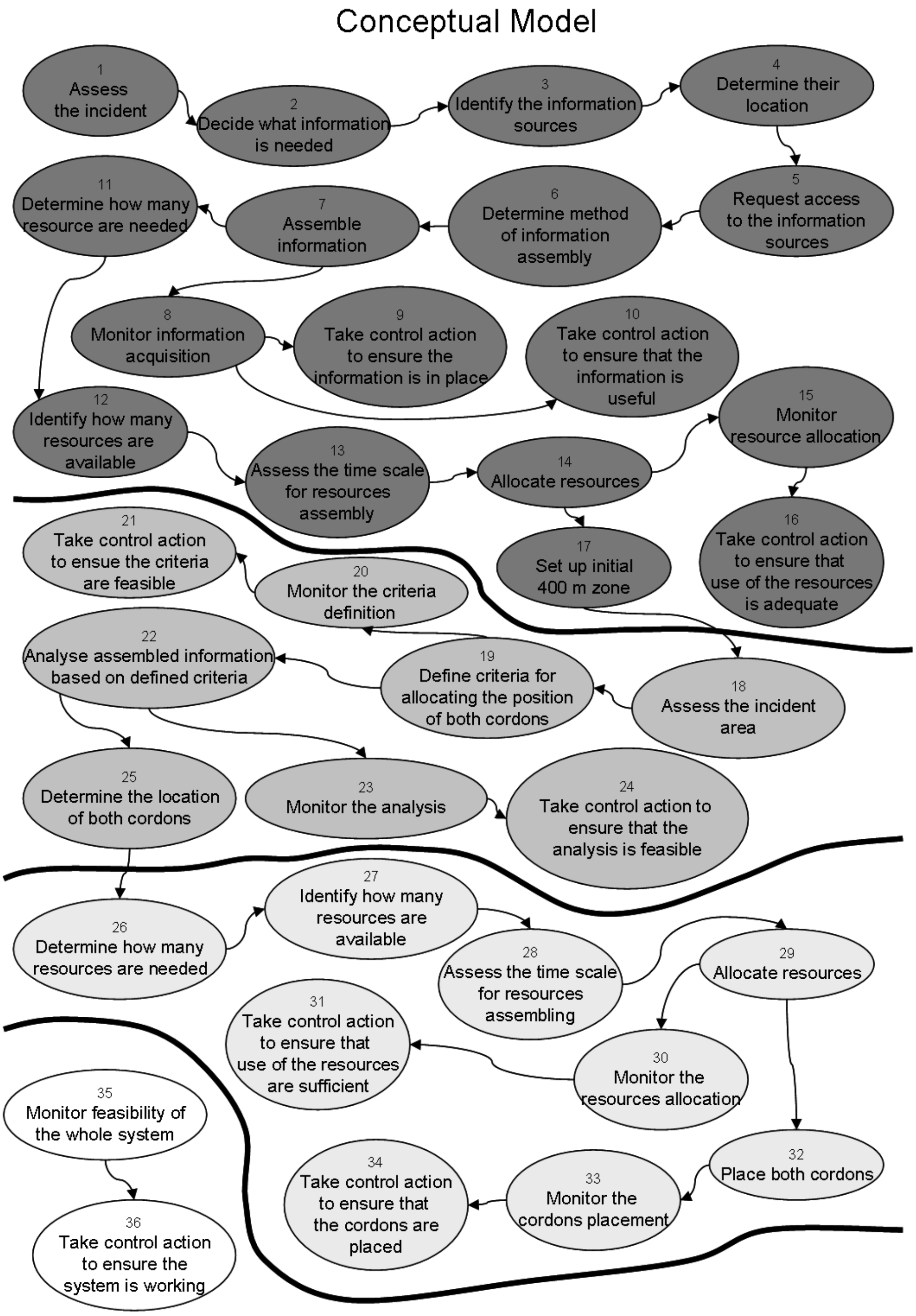


Figure 5: Conceptual model of CBRN incident scene management system.

needs to be then fused with information extracted from underlining data sources: database containing information about behaviour of CBRN substances (CHEMDATA), meteorological data, basic topographic map and digital elevation model of the area. The general function of the first subsystem is to deliver all necessary information for the decision making processes and analyses. These are the core activities of the conceptual model and are represented in the second subsystem. The third subsystem corresponds to the actual placement of the inner and outer cordon zones around the incident scene and is based on the outputs of the second subsystem.

To ensure coherence of the model each of the activities needs to be monitored to determine whether it is performing at acceptable levels. Beside, control actions have to be specified to guarantee the achievement of the purpose defined by the root definition (Wilson, 2001).

4.4 Step 4: Comparison of conceptual model with real world

The conceptual model is compared with the real world as expressed in the rich picture. Checkland and Scholes (1990) argue that the most common way of comparison in SSM is formal questioning where the conceptual model is used as a source of questions that should be asked of the real world. In general, each activity identified in the conceptual model is evaluated. A description of how the activity is currently realised is recorded. Subsequently, an investigation of potential changes is undertaken together with the system stakeholders and one or more alternative solutions is suggested.

The produced conceptual model of the CBRN incident scene management system demonstrates the complexity of the whole process. Since this research project concentrates on automation of the decision processes only the most relevant activities have been selected for the analysis. Therefore, only activities related to the second subsystem are evaluated. However, having produced the conceptual model of the whole system, any additional activity can be analysed in later stage of the research if needed. A table demonstrating the comparison process is displayed in Figure 6. The "How" column depicts how are the activities currently managed. The last column "Alternatives" summarises the possible changes to the system to improve its functionality.

5 Further work

The aim of this research project is to capture, formalise, and if possible improve the current decision making process that first responders use when searching for the best location in which to place inner and outer cordons delimitating large CBRN incidents. The next step will be to compile a set of generic rules related to the second subsystem of the conceptual model i.e., information analyses and decision making processes of the incident commanders. The implementation of such rules will be tested using a number of different computational methodologies e.g. cost surface analysis, simulated annealing, agent-based

Comparing Conceptual Model with Real World

Activity in model	Exist?	How?	Who?	Judgement	Alternatives?
2. Decide what information is needed	Yes	Discussion	Bronze commanders	Slow	Have implicit access the curtail information sources
17. Set up initial 400 m zone	Yes	The incident is localised on a paper map and the approximate 400m zone is identified	Bronze commanders	Resources are not available	Localise the incident on a digital map, set up initial parameters, generate approximate inner and outer cordon locations based on the initial information
18. Assess the incident area	Yes	Well protected personnel approach the 400 m zone upwind, upslope and collect information about the incident site; 'CHALET'[1]	FRS, Police in gas tight suits with CBRN detection device	Slow	Some information can be collected with use of sensors, CCTVs
19. Define criteria for allocating the position of both cordons	Yes	Discussion; Ad-hoc definition of the criteria based on the experience, local knowledge and results from the incident site assessment	Silver commanders	Not organised	A digital system with all the general criteria captured, the user has a possibility of altering some of the parameters
20. Monitor the criteria definition	Yes	Tactical updates every 20 minutes; risk assessment and progress monitoring	Bronze commanders	Not suitable for all personnel	Digital logs accessible by the silver commanders for situation awareness
21. Take control action to ensure the criteria are feasible	Yes	Referring back to the information sources, SOP, OPS1, TIF and TID documents	Bronze commanders	Slow and not organised	Digital logs accessible by the silver for situation awareness
22. Analyse assembled information based on defined criteria	Yes	Discussion; ad-hoc analysis with no use of digital tools	Silver commanders	Slow and not organised	A digital tool which is capable of downloading all necessary information, allowing the user to enter additional information from incident site assessment, undertaking the analysis and providing results
23. Monitor the analysis	Yes	Monitoring the progress based on the SOP, OPS1, TIF and TID documents	Silver commanders	Not sufficient	Digital logs recording every analysis, its input and results
24. Take control action to ensure that the analysis is feasible	Yes	Referring back to the information sources, SOP, OPS1, TIF and TID documents; operational debrief	Silver commanders	Not organised	No alternative
25. Determine the location of both cordons	Yes	The location of both cordons is drawn on a paper map based on the output of the analysis; it is ready for distribution to bronze	Silver commanders	Slow	Optimised location of both cordons given as an output of the digital analysis, the positions are drawn on a digital map and are ready to be distributed via Internet, CD, GSM etc.
35. Monitor feasibility of the whole system	Yes	Analytical risk assessment; tactical meetings every 20 minutes (offensive, defensive)	Silver/ Gold commanders	Not suitable for all personnel	Every step is listed and ticked when implemented, a record of who has implemented what task is kept
36. Take control action to ensure the system is working	Yes	Operational debrief, regular meetings of command support unit	Silver/ Gold commanders	Sufficient	No alternative

[1] 'CHALET'
C: Casualties - approximate numbers of dead, injured and uninjured
H: Hazards- present and potential
A: Access- best access routes for emergency vehicles
L: Location- exact location of the incident
E: Emergency- emergency services present and required
T: Type- type of incident with brief details of numbers of vehicles, buildings etc, involved

Figure 6: Comparing the conceptual model with real world.

modelling, etc. Hypothetical scenarios will then be simulated for a major CBRN incident within Nottingham city centre.

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References

Batty, M., Desyllas, J., and Duxbury, E. (2003). Safety in Numbers? Modelling Crowds and Designing Control for the Notting Hill Carnival. *Urban Studies*, **40**(8), 1573–1590.

Checkland, P. and Scholes, J. (1990). *Soft Systems Methodology in Action*. Wiley, Chichester.

Civil Contingencies Act (2005). *Civil Contingencies Act*. HMSO, Chapter 39.

Couprie, D., Goodbrand, A., Li, B., and Zhu, D. (2006). *Soft Systems Methodology: A report*. [online], Available at: <http://sern.ucalgary.ca/courses/seng/613/F97/grp4/ssmfinal.html>, (accessed 6/11/2006). Department of Computer Science, University of Calgary.

de Silva, F. (2000). Challenges in Designing Spatial Decision Support Systems for Evacuation Planning. Natural Hazards Research Working Paper number 105, Natural Hazards Research and Applications Information Centre, Institute of Behavioural Science, University of Colorado, USA.

HM Government (2005). *Emergency Response and Recovery: Non-Statutory Guidance to Complement Emergency Preparedness*.

Kitano, H., Tadokoro, S., Noda, I., Matsubara, H., Takahashi, T., Shinjou, A., and Shimada, S. (1999). RoboCup Rescue: Search and Rescue in Large-Scale Disasters as a Domain for Autonomous Agents Research. In *IEEE International Conference on Systems, Man, and Cybernetics; Tokyo, Japan,*, volume 6, pages 739–743.

Monk, A. and Howard, S. (1998). The Rich Picture: A Tool for Reasoning About Work Context. *Interactions*, **5**(2), 21–30.

Open Geospatial Consortium, I. (2006). *The OGC Announces Call for Participation in OWS-4 Testbed*. [online], Available at: <URL: http://www.opengeospatial.org/>, (accessed: 7/2/2007).

Turoff, M., Chumer, M., van de Walle, B., and Yao, X. (2004). The Design of a Dynamic Emergency Response Management Information Systems (DERMIS). *Journal of Information Technology Theory and Application (JITTA)*, **5**(4), 1–36.

van Borkulo, E., Scholten, H. J., Zlatanova, S., and van de Brink, A. (2005). Decision Making in Response and Relief Phases. In P. J. M. van Oosterom, S. Zlatanova, and E. M. Fendel, editors, *Geo-information for Disaster Management - late papers*, pages 47–54.

Wilson, B. (2001). *Soft Systems Methodology: Conceptual Model Building and its Contribution*. John Wiley & sons, Chichester.

Biography

Věra Karasová is a PhD student at the Centre for Geospatial Science, University of Nottingham. Her research focuses on formalisation of decision processes of incident commanders during a response to large CBRN emergencies in an urban area. She started her university studies in Geodesy and Cartography at the Czech Technical University in Prague, Czech Republic, and obtained her M.Sc. degree in Geomatics at the Institute of Cartography and Geoinformatics, Helsinki University of Technology, Finland.