# BRIDGE Risk Analyzer: A Collaborative Tool for Enhanced Risk Analysis in Crisis Situations[1]

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**Abstract.** When a crisis occurs, such as a fire in a chemical facility, difficult decisions need to be made based on assessment of risk. Is it safe enough for responders to enter the area? Do we need to evacuate the public from the nearby area? Assessing risks may require information from a number of different sources, as well as collaboration across organizations and management levels. In this paper we present ongoing work to develop a collaborative tool to support risk analysis in crisis situations. The tool will be tightly integrated with a complementary tool to make coordinated situation assessments, planning, decision making, information gathering and sharing, thereby providing a unified and integrated crisis management support facility.

**Keywords:** Risk analysis, crisis management

## 1 Introduction

Crisis management is a highly challenging task. Big decisions need to be made based on information from a number of different sources, such as detectors, sensors, bystanders, the public, on-site responders, and external domain experts. Successful crisis management depends on the ability to identify and obtain the relevant information, as well as to process this in a way that provides a good basis for making decisions. A recent example from Norway showed how unavailability of operational information, partly due to poor and outdated ICT solutions, contributed to the escalation of a major crisis [16, pp. 332–334]. These challenges are a major motivation for the BRIDGE project (http://www.bridgeproject.eu). Focusing on large-scale emergency management and the ubiquity of ICT support, the project aims to facilitate cross-border and cross-agency collaboration, allow the creation of a common, comprehensive, and reliable operational picture of the incident site, enable integration of resources and technologies into workflow management, and enable active ad-hoc participation of third parties.

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Risk analysis is an essential prerequisite for decision making. Ensuring that the different actors involved in the crisis management and response have a shared understanding of the relevant risks is an important contribution to establishing shared situation awareness and a common operational picture. In this paper we present ongoing work to develop a collaborative tool to support risk analysis in crisis situations, called the BRIDGE Risk Analyzer (BRA). The BRA will be closely coupled with a tool, called the BRIDGE Master [1], for supporting coordinated situation assessments, planning, decision making, information gathering and sharing. The Master provides, among other things, functionality for visualization and management of all collected information and available resources during an incident and integration with hand held devices to be used in the field. Together, the BRA and the Master will contribute to a unified and integrated crisis management support facility.

In this paper we present the method used for researching and developing the BRA as well as our current results and findings. The paper is structured as follows: In Sect. 2 we present the general research and development method used. A description of how this method has been instantiated in the first and second iteration is given in Sect. 3 and Sect. 4. In Sect. 5 we present related work, before concluding in Sect. 6.

## 2 Method

As research and development method we adopt an approach to technology research provided in [21]. The approach is focused on development of new and better artifacts and prescribes an iterative process of three phases.

The first phase – *problem analysis* – is concerned with identifying the needs for new and better artifacts. This should preferably be done in interaction with potential users and other stakeholders. In the second phase – *innovation* – the goal is to construct an artifact that satisfies the identified needs. The third and final phase – *evaluation* – is an investigation into whether or not the artifact actually satisfies the needs. In order to do this investigation, hypotheses and predictions concerning the artifact must be formulated based on the needs. Then these must be tested using a selection of established research strategies. (For an overview of research strategies, see [13, pp. 31–34]; the research strategy chosen for the early iterations in the research and development of the BRA can be classified as *judgment studies*.)

## 3 First Iteration Based on Paper Prototype

For the initial iterations we chose to use a lightweight instantiation of the method. The goal was to quickly reach a point where we had something concrete that could be presented to experts in the crisis management domain. This approach would ensure that we would receive feedback and corrections for bad ideas at an early stage.

### 3.1 Problem Analysis: Literature and Discussions

Our initial problem analysis was carried out as an informal process where we acquired knowledge about the crisis management domain in general and risk analysis during crisis situations in particular mainly through literature, brainstorming and discussions. Typical resources that we drew upon included literature and investigation reports such as [5,17,19]. Moreover, we obtained domain knowledge through the Emergency project (http://heim.ifi.uio.no/~ketils/emergency/the-emergency-project.htm) which aims to improve decision support in emergency situations. Finally, we drew upon our general knowledge about risk analysis.

The above process allowed us to establish the following initial set of requirements for a tool, targeted toward the incident command level, to support risk analysis in situations where the decision frame is longer than a few minutes: **R1**: Be simple and intuitive to use. **R2:** Support identification and assessment of potential risks toward the safety of responders or the public, infrastructure, the environment, or other assets. **R3**: Facilitate exploitation of preparatory risk analyses performed before the crisis. **R4**: Support editing/updating of risk models during the crisis. **R5**: Support geographical location of risks. **R6**: Support identification of information that is typically needed to assess risks. **R7**: Facilitate participation of actors, such as domain experts, not present at the incident site in the analysis.

### 3.2 Innovation: Paper Prototype

Following the strategy of a lightweight approach to the first iteration, the first artifact was developed as a paper prototype [20] of an application to be deployed on an interactive multi-user touch table. Paper prototypes can be developed with little resources, while still providing a good basis for discussions and feedback. Fig. 1 shows a picture of a part of the paper prototype. Although it aimed to fulfill all the requirements above, space restrictions mean that we must limit ourselves to explain some of the central aspects.

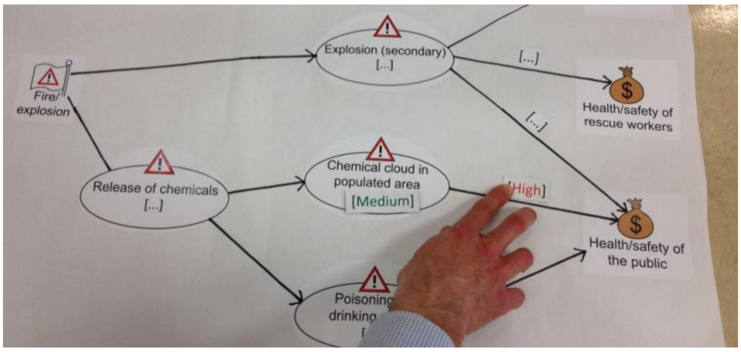


**Fig. 1.** Paper prototype of the BRA demonstrated at the evaluation workshop

We chose to use graphical risk models expressed in a simplified version of the CORAS language [12]. The CORAS language was developed in order to be easily understood, and from other domains we have positive experiences with using CORAS models during risk analysis sessions involving actors from very different backgrounds. Moreover, we believe that graphical models are well suited for use with a touch interface. The functionality includes interacting with the model and sending information request to external experts.

**Table 1.** Evaluation of predictions

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|---|---|
| P1.1 | The Oslo participants found the tool useful for the command center, but wanted simpler support for the incident command. This was modified after we explained that a library of predefined risk models would be used, so that risk models need not be built from scratch during the crisis. One participant seemed to disagree that the tool was too complicated for the incident command. Still, our overall impression was that a simpler tool is wanted for the incident command level, so P1.1 was not confirmed. Interestingly, the Lancaster participants found the models too simple to be used by scientific or technical advisors, but suitable for local authorities and police, and possibly also for informing the press and the public. |
| P1.2 | As far as we could observe, all participants quickly grasped the meaning of the models. They did not ask questions that indicated misunderstandings or incomprehension. We therefore consider that P1.2 was confirmed. |
| P1.3 | The functionality for requesting support from external experts was only briefly explained due to time restrictions. It did not raise further discussion or comment from the participants. Our impression is that this was seen as a useful feature, but a clear evaluation of P1.3 could not be made at that point. |
| P1.4 | A need for a list of risk treatment options that is related to different risk levels, so that different options are proposed depending on the risk level was suggested. This means that P1.4 was falsified. |
| P1.5 | Apart from the comments described in the evaluation of P1.1, the participants' feedback did not indicate that any of the features were unsuitable or redundant. |

### 3.3 Evaluation: Workshop

The paper prototype was evaluated primarily through workshops organized by BRIDGE [1] in Oslo 29/9-2011 and in Lancaster 16/4-2012[2]. The workshops included interactive sessions where the paper prototype was presented to experts from the crisis/emergency domain and the experts were asked questions and encouraged to give their feedback. Three experts participated in this session in the Oslo workshop, while two experts participated in the Lancaster workshop. Although not explicitly formulated as such prior to the workshops, our underlying hypothesis (H), and the predictions

[2] BRIDGE also organized a similar workshop in Delft 6/12-2011. However, in this workshop we presented a version of the BRA for mobile devices, so this is less relevant for this paper.

(P) derived from the hypotheses, can be captured as follows: **H**: The tool adequately supports the incident commanders and their assistants w.r.t. risk analysis during large-scale crisis management. **P1.1**: The workshop participants will consider the BRA easy to use for incident commanders and their assistants. **P1.2**: The workshop participants will easily understand the graphical risk model. **P1.3**: The workshop participants will find the possibility to requesting support from external experts to be useful. **P1.4**: The workshop participants will not identify additional features that they consider necessary. **P1.5**: The workshop participants will not consider any of the presented features redundant or unsuitable.

Table 1 summarizes our evaluation of the predictions based on an informal analysis of notes and video recordings of the workshops. We can of course only draw preliminary conclusions to be followed up by more systematic investigations later.

## 4 Second Iteration Based on Executable Prototype

In the second iteration we focused on building an executable prototype, but still doing fairly lightweight evaluation. The goal was to present something that resembles the final artifact to get feedback on design decisions at an early development stage.

### 4.1 Problem Analysis: Refinement Based on Workshops and Interaction

The second problem analysis was primarily based on the evaluation from the first iteration. Perhaps the most fundamental feedback was the considerations regarding the target group. Workshop participants had expressed doubt as to whether the tool was simple enough for use by the incident command, but they had also stated that it would be useful for the command center, and that it could help making better assessments. This, together with the fact that a command center will typically be more involved in a large emergency than the smaller incidents, and that BRIDGE is concerned with large-scale emergencies, led us to change the target group for the tool to include the command center, rather than to discard the design. This means that we added the requirement that it should be possible to use the tool cooperatively both at the command center and the incident command. We envision that the command center personnel will typically do most of the actual tailoring and editing of risk models during the crisis, while the incident command will be able to see the results and make adjustments as they see fit. This harmonizes well with the idea that the higher command levels should provide support for the on-site responders. However, the tool itself should not place strong restrictions on how the work is divided between the levels, as feedback from the workshops indicates that the level of sophistication of support tools used by the incident command level can vary greatly. We plan to develop a simpler version for mobile devices later, but this is beyond the scope of this paper.

The evaluation after the first iteration also led to the inclusion of a requirement based on the proposal described under the evaluation of P1.4. Hence, the list of requirements from Sect. 3.1 is extended with the following: **R8**: Facilitate collaborative use of the tool at the command center and the incident command. **R9**: Support identification of proposed risk treatments that depend on estimated risk level.

### 4.2 Innovation: Executable Prototype

The executable prototype of the BRA is developed as a Microsoft PixelSense (http://www.pixelsense.com) application for the Samsung SUR40. Samsung SUR40 is a computer built as a table with the table top made up by a 40" multi-touch screen. Fig. 2 shows the prototype BRA deployed on the touch screen table. In addition to functionality for creating and editing simplified CORAS diagrams, the prototype also connects to middleware developed in the BRIDGE project. Through this middleware it exchanges messages with the Dynamic Expertise Integration Network (DEIN) [18], a system for communicating with off-site experts as part of the crisis management. In summary we can say that the development of the executable prototype during the second iteration focused on the fulfillment of requirements R1, R2, R4 and R7 defined in Sect. 3.1, while requirements R3, R5 and R6, as well as requirements R8 and R9 defined in Sect. 4.1 were postponed to later iterations.

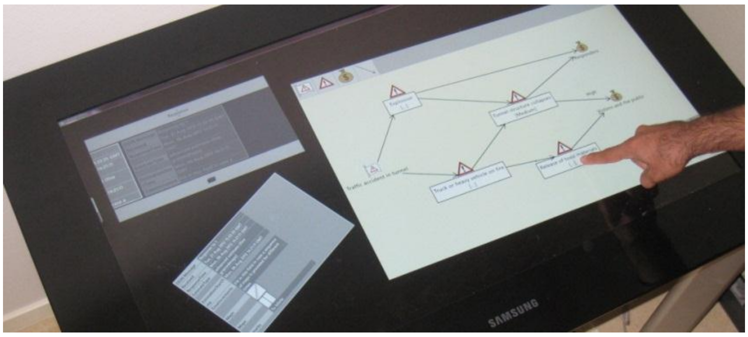

**Fig. 2.** Executable prototype of the BRA deployed on a Samsung SUR40 table

### 4.3 Evaluation: Demonstration

For the second evaluation of the BRA, the prototype was featured as one of several tools in a project wide demonstration of BRIDGE, held in VersuchStollen Hagerbach (http://hagerbach.ch ) in September 2012. The BRA was used to review risks of escalation of a crisis and to send risk specific requests for information through the DEIN system. At the time of writing, we are still waiting for the participants' feedback.

The overall hypothesis **H** from the first evaluation remains the same, except that we included command center personnel in the target group. Due to the different nature and focus of the second evaluation, new predictions were formulated to fit the particularities of the demonstration: **P2.1**: The domain experts consider the use of risk models in the BRA as a useful tool for use at the command center and the incident command. **P2.2**: The domain experts consider sending requests for information to DEIN from BRA a useful feature to support the risk analysis. **P2.3**: The domain experts do not consider any of the demonstrated features of the BRA redundant or unsuitable.

## 5 Related Work

The study of the effectiveness of visual or graphical communication of uncertainty and risk goes back a couple of decades, though according to a survey from 1999 [11], studies testing visual aids in risk communication until that point in time were few. In one of the first studies [8] a group of non-technical was people subjected to a number of graphical means for visualizing uncertainty. This study showed that how uncertainty is presented by graphical means is relevant for how it is perceived. A study of communication of health risks [3] found that the respondents preferred a presentation combining a short text and an illustration over a longer piece of text. The 1999 survey [11]concludes that the evidence available in 1999 points in the direction that visual aids are useful for communicating risk, but that the tasks of the reader (the purpose of the communication) always must be considered when choosing what aids to apply. Research on the CORAS language [6,7] indicates that a simple iconography combined with text labels is effective in communication of risk, and thus points in the same direction as earlier research.

In [2] a risk model, expressed in the CORAS language, for forest fires is developed based on a process similar to risk and emergency preparedness assessment in the offshore industry [15]. The model is parameterized by influence factors such as the direction and speed of the wind and the quality of the wood. In [4] an interactive map-based tool capable of visualizing risk is presented. This tool has inspired certain aspects of the BRA.

There exist a number of computerized support tools for incident management, such as Essential Incident [9], opsIncident [10] and E Team [14]. They all provide support for information collection and, to varying degree, risk analysis. However, we are not aware of any tool that uses graphical risk models to be viewed and updated on a multi-user interactive touch table in a way similar to the BRA.

## 6 Conclusions and Future Work

Focusing on the method of research and development as well as the results, we have presented ongoing work to develop a collaborative tool to support risk analysis in crisis situations. Our goal is to provide, in conjunction with the BRIDGE Master, a unified and integrated crisis management support facility. Although results so far are promising, a number of issues still need to be addressed in later iterations.

The next step in the research and development process is obviously to evaluate the outcome of the demonstration described in Sect. 4.3, before initiating a new iteration of the process. In the problem analysis step of this third iteration the evaluation of the demonstration will be used to revise the list of requirements. The innovation step will focus on further development of the executable prototype to support the requirements not addressed so far. Requirements R5 and R6 will be supported by integrating with the BRIDGE Master and thus making its features and information available to the BRA. Requirements R3 and R8 will be supported by a risk model repository to hold preparatory risk models as well as risk models shared among several instances of the BRA. Requirement R9 will be supported by automated reasoning based on the information provided to the BRA and conditions specified in the preparatory risk models. The evaluation of the third iteration will be a second demonstration where the focus will be on the user interfaces of the BRIDGE system.

## References


1. BRIDGE Newsletter, no. 2 (2012)
2. Brændeland, G.: Forberedende beslutningsrisikoanalyse for håndtering av skogbrann i Elverum kommune. Technical report A17367, SINTEF ICT (2011) [In Norwegian]
3. Connelly, A.N., Knuth, B.A.: Evaluating risk communication: Examining target audience perception about four presentation formats for fish consumption health advisory information. Risk Anal. 18(5), 649–659 (1998)
4. Eide, A.W., Stølen, K.: Geographic visualization of risk as decision support in emergency situations. In: 5th International Conference on Human System Interaction (HSI'12) (2012)
5. Flin, R.., Arbuthnot, K. (eds.): Incident Command: Tales from the Hot Seat. Ashgate Publishing Company (2002) [Reprinted 2008]
6. Grøndahl, I.H., Lund, M.S., Stølen, K.: Reducing the Effort to Comprehend Risk Models: Text Labels Are Often Preferred Over Graphical Means. Risk Anal. 31(11), 1813–1831 (2011)
7. Hogganvik, I., Stølen K.: A graphical approach to risk identification, motivated by empirical investigations. In: 9th International Conference on Model Driven Engineering Languages and Systems (MoDELS'06). Lecture Notes in Computer Science, vol. 4199, pp. 574–588. Springer (2006)
8. Ibrekk, H., Morgan, G.: Graphical communication of uncertain quantities to nontechnical people. Risk Anal. 7(4), 519–529 (1987)
9. IHS. Essential Incident. Flyer (2010)
10. IHS. opsIncident. Flyer
11. Lipkus, M.I., Hollands, J.G.: The visual communication of risk. J Natl Cancer Inst Monogr. 25, 149–163 (1999)
12. Lund, M.S., Solhaug, B., Stølen, K.: Model-driven risk analysis. The CORAS approach. Springer (2011)
13. McGarth, J.E.: Groups: interaction and performance. Prentice-Hall (1984)
14. NC4. E Team. Flyer (2011)
15. NORSOK Standard Z-013: Risk and emergency preparedness assessment. Edition 3 (2010)
16. NOU 2012:14: Rapport fra 22. juli-kommisjonen (2012) [In Norwegian]
17. NOU 2001:9: Lillestrøm-ulykken 5. april 2000 (2001) [In Norwegian]
18. Pavlin, G.: Dynamic Expertise Integration Network (DEIN): User Manual (Draft), Version 0.6. Thales Research and Technology
19. Rake, E.L.: Crisis Management. Coping and decision making on-scene. Ph.D. thesis, University of Stavanger (2008)
20. Snyder, C.: Paper prototyping. IBM developerWorks (2001)
21. Solheim, I., Stølen, K.:Technology research explained. Technical report A313, SINTEF ICT (2007)