The International Emergency Management Society
9th Annual Conference Proceedings
University of Waterloo, Canada, May 14-17, 2002

DATA COLLECTION IN RESCUE OPERATIONS

Mirko Thorstensson

Swedish Defence Research Agency[1]

Keywords: rescue operations, data collection, debriefing, AAR, learning

Abstract

Rescue operations are complex distributed activities. First response, incident command and rear support have to be coordinated under time pressure and safety critical conditions. Analysing an operation and learning from the experience is problematic because spatially separated units, heterogeneous systems and fragmentary information make it difficult for participants, managers and researchers to grasp the ramifications of a complex scenario. In training, multimedia representations of rescue operations support after-action reviews, post-mission analyses and distance learning by providing coherent and persistent representations of exercises. In this paper we investigate how methods and tools developed in a training context can be adapted to support reconstruction and exploration of real rescue operations as a basis for experience-based learning and operational development. Specifically, we study the requirements and limitations on data collection in real rescue operations in relation to emergency-response training. We elaborate on the consequences of the differences in data collection abilities for documenting an involved scenario, analysing the facts of the event and communicating the results and findings.

Introduction

Rescue operations after catastrophic events such as train or aeroplane crashes, chemical accidents or acts of terrorism are complex and demanding tasks. First responders from different rescue organisations have to collaborate in the field to save lives and property. Command, control and communications must be performed in a temporarily composed taskforce comprising units from multiple agencies. To acquire and sustain the ability to perform joint rescue operations, the rescue agencies need to devise appropriate plans, develop standard operating procedures, and design common training programs (Jenvald, 1999). All these tasks require a fundamental understanding of the processes involved in a rescue operation and their interaction (Flanagan, 1954, Raths, 1987; Salas, Dickinson, Converse & Tannenbaum, 1992; Fredholm, 1996). To learn and improve from past experience the responders need to reflect on the rescue performance in relation to the specific incident (Lederman, 1992). Hoffman, Crandall and Shadbolt (1998) identified two reasons why participants may have difficulties learning from past experience. First, in a distributed operation, actions taken at one location may have effects at other locations, which may lead to a lack of feedback on the performance. Second, when looking back on stressful situations people may confuse similar situations in different operations.

[1] Swedish Defence Research Agency FOI
P.O. Box 1165, SE-581 11 Linköping, Sweden
mirtho@foi.se

In 2001 we initiated a research project (Jenvald, Johansson, Nygren, Palmgren, 2001b), together with the Swedish Rescue Services Agency and the Linköping Fire Department, with the goal to increase the possibility for the responders in the rescue community to systematically learn from real operations as well as from exercises. We aim at providing the rescue forces with methods and tools appropriate for conducting constructive after-action reviews (AAR) (Rankin, Gentner & Crissey, 1995; Gentner, Cameron, & Crissey, 1997; Morrison & Meliza, 1999) with all personnel participating in an incident. The goal is to devise instruments that the responders can use to document rescue operations as a basis for reflection and learning. We adopt a bottom-up approach by supporting the responders with procedures for automated registration of operational activities. The recorded data are combined with a conceptual model of the rescue organisation to form a dynamic computer model of each operation (Morin, Jenvald & Thorstensson, 2000). The rescue personnel can review these models using the MIND visualisation framework (Morin, 2001) to examine the various phases of the operation.

In this paper, we present means of recording the activities of real rescue operations with the goal to provide feedback to the responders after each incident. Ideally, the quality of the feedback should be the same as during full-scale emergency response training (Morin, Jenvald & Worm, 1998; Jenvald, 1999; Crissey, Morin & Jenvald, 2001; Thorstensson, Björneberg, Tingland, & Tirmén Carelius, 2001). However, a real operation sets certain demands on data collection methods. Bearing this in mind, we study the requirements and limitations on data collection in real rescue operations in relation to emergency-response training. Finally, we elaborate on the consequences of the differences in data collection abilities for documenting different rescue activities and present our findings.

From training to real operations

Methods and tools for supporting training of emergency response have been reported by Jenvald and his colleagues (Jenvald, 1999; Morin et al., 1998; Crissey et al., 2001). Based on these results we ask whether it is possible to support constructive AAR after real operations in a similar manner. To this end, we explore the differences between live operations and training exercises. We have identified the following differences:

- *Observers cannot be used*. In a training situation we can use observers to collect data. In a live operation all available personnel will be handling the emergency.
- *Absence of trainers*. In live operations there are no trainers available to provide feedback on performance and instruction to correct behaviour.
- *No control of the emergency.* In a training situation trainers can control the evolving situation and adapt it to training needs and unit performance. This option is not available in live operations.
- *Intrusive methods for registration are not viable*. All data collection, automated or manual, that limits unit performance must not be used.
- *Stress and danger*. In live operations there are always elements of stress and danger that influence the outcome of the operation.

Nevertheless, a realistic exercise resembles a real operation in many respects. The following factors are similar in training exercises and real operations:

- *Operational success factors*. A realistic exercise is constructed to reflect the factors for operational success that are valid in the real operation.
- *Organisation*. A live exercise is performed with the same organisation that would respond to a real emergency.
- *Command and control structure*. The command and control (C2) structure in an exercise is supposed to be the same as in a live operation.

- *Standard operational procedures.* The procedures trained in an exercise are to be used in live emergencies.
- *Equipment.* The same equipment is used in training as in live operations.
- *Problems.* The purpose of most training scenarios is to emphasize the problems encountered in real operations to help commanders and response personnel to acquire knowledge and experience.

In the light of the differences and similarities listed, we argue that the core methods and tools developed for training can be adapted to support real operations as well. However, in real operations, data collection methods and tools must be seamlessly integrated in operational procedures. They must be devised to be automatic and robust.

Reconstruction and exploration

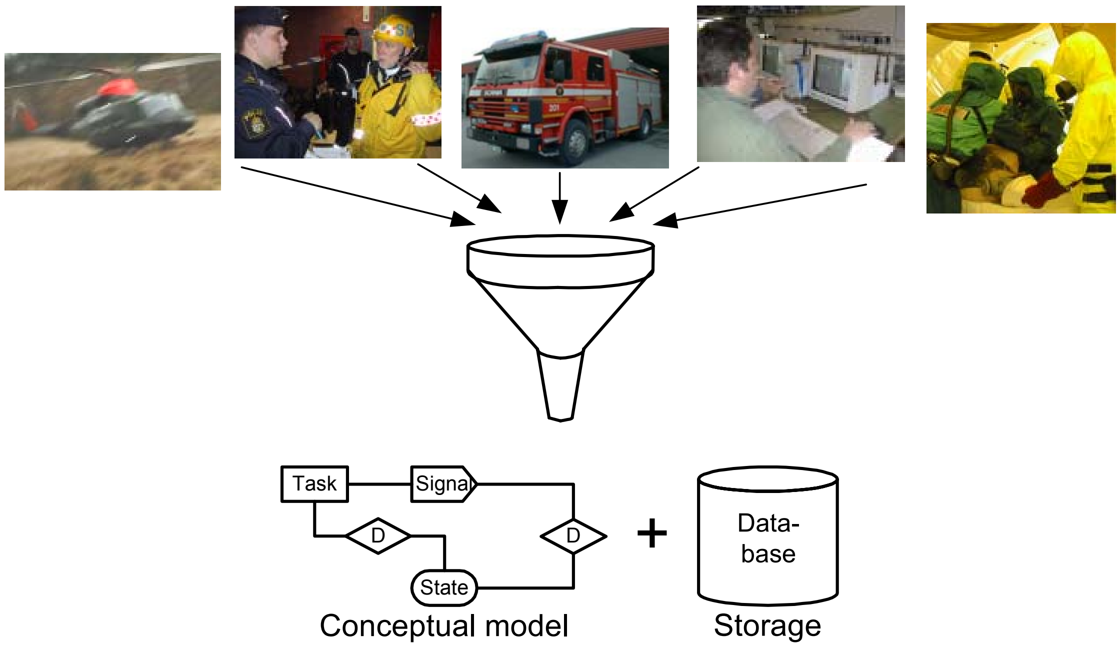
Our method addresses the problem of how to transform operational objectives into goals for the visualisation of the operation, and how these goals direct the modelling of the operation (Morin et al., 2000). The end result of this undertaking is a *mission history* (Morin et al., 1998), which is an executable, discrete-event model of the rescue operation. A mission history is made up of hierarchical object models, representing the units participating, and a sequence of events that represents the state transitions that take place in those objects. Each event is marked with the time when it occurred during the operation. Mission histories are similar to behavioural protocols (Woods, 1993) in that they include data from a variety of sources about the behaviour of people in relation to changes in an underlying process—in this case, a rescue operation.

Construction and visualisation of a mission history rely on the methods and tools to collect data from a rescue operation, to compile and appropriately organise these data and to present them using comprehensible displays and views, such as digital maps and diagrams. These tasks are performed by an *instrumentation system*. For our field experiments we have used the MIND system (Jenvald & Morin, 1998; Thorstensson, Morin & Jenvald, 1999; Jenvald, 1999). MIND is an adaptive and flexible research framework with integrated presentation components, which includes displays for tactical maps, annotated photographs from the operation, recorded tactical radio communications, command and control (C2) system logs and compiled statistics about unit performance. Figure 1 gives an overview of the process constructing a mission-history.

The method for constructing a mission history includes the following steps:

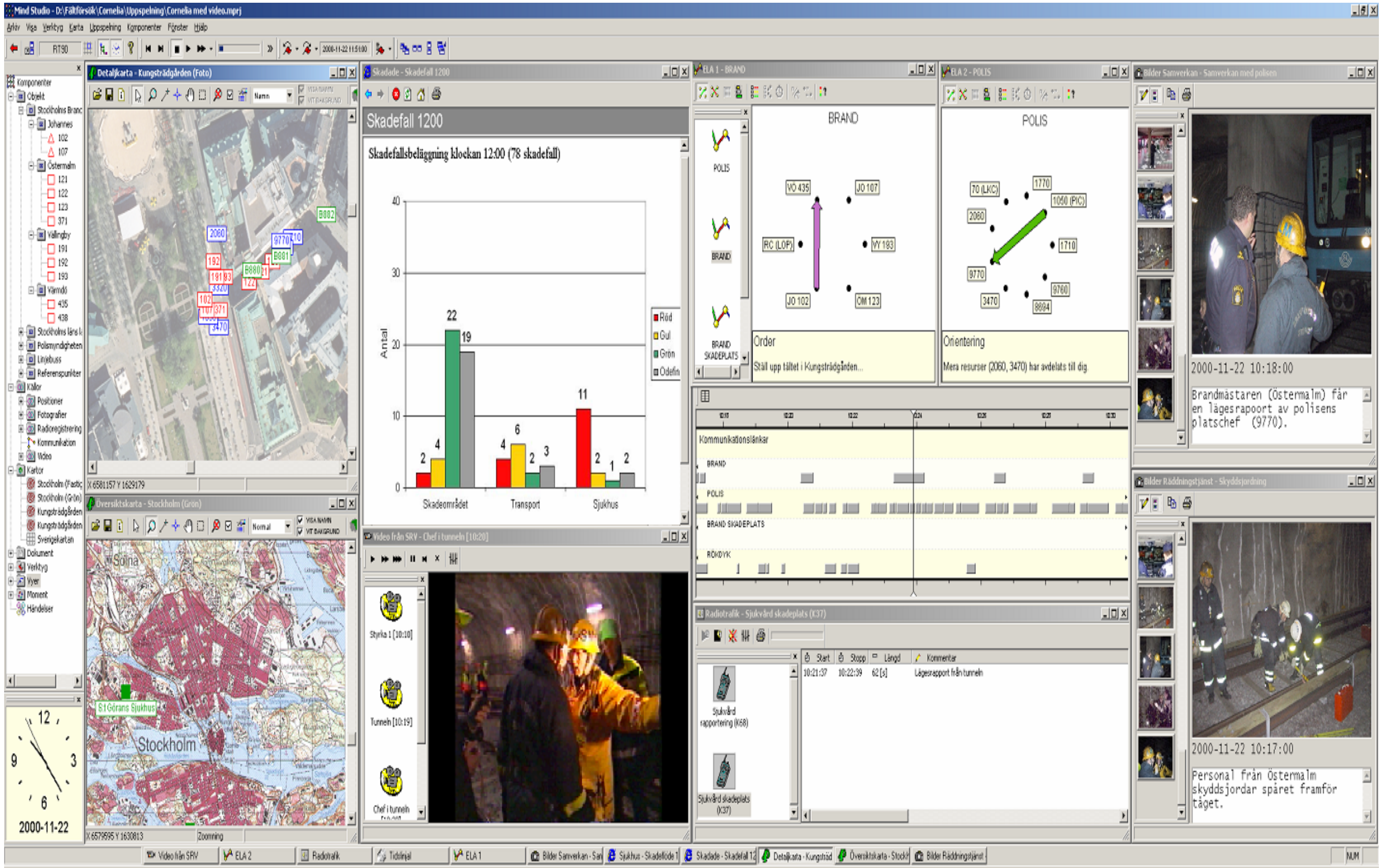
- Identify crucial objects and procedures which must be represented
- Model each object with respect to relevant parameters regarding what needs to be known and what can be measured
- Apply methods and equipment for data collection
- Record data from the operation
- Compile data in an executable mission history
- Visualize the model for the specific need

Figure 1: The process of modelling a rescue operation to construct a mission history. A conceptual model of objects and procedures in the operational domain is combined with data collected during the operation to form an executable model of the operation for subsequent exploration.



The mission history can be used for different purposes over time (Jenvald, Morin & Kincaid, 2001). Immediately after the operation an AAR supports debriefing of participants. After some time a post-mission in-depth analysis can facilitate the evaluation of unit performance and the development of tactics and plans (Jenvald, Rejnus, Morin & Thorstensson, 1998; Rejnus, Jenvald & Morin, 1998). All documented operations can also be used for training purposes (Murray, 1994) in classroom teaching and as multimedia sets for individual studies (Jenvald, Morin & Rejnus, 2000). Figure 2 shows a screen shot from the MIND system executing a mission history from a rescue operation exercise in the Stockholm underground (Thorstensson et al., 2001b).

Figure 2: A screen shot from the MIND system displaying a mission history from a rescue operation exercise in the Stockholm underground. The incident included the derailment of a train in a tunnel in the Stockholm subway. Some 80 casualties and 200 responders took part in the live exercise.



Data collection

Data collection is the process of gathering the data needed to build the mission history. It takes place during an operation and is implemented as a collection of manual or automatic procedures. The most fundamental strategy to use when recording sensor information is to use sensors with a built-in accurate clock to be able to meet the requirements of the discrete event model.

Ideally, all data can be acquired through automatic procedures, either from existing systems or from data-collection devices attached to the units in the operation. In the training settings, specially assigned and trained observers may collect data manually (Thorstensson, 1997). In general, we can choose between different available data sources. Data sources have different properties both in technical terms (for example concerning resolution and accuracy) and in economical terms (the cost in relation to the amount and quality of data provided). In some cases it might even be justifiable to modify existing methods and techniques to meet particular operational requirements.

The emergency personnel are important sources of information in a rescue operation, but there are some aspects that must be considered. First responders in a time-critical operation in a hazardous environment must not be diverted from their primary objectives. Resource demanding data-collection tasks are impropriate. However, there are methods that can be used in retrospect. The critical incident technique (CIT) (Flanagan, 1954) and the derivate critical decision method (CDM) (Hoffman, Crandall & Shadbolt, 1998; Klein, Calderwood & MacGregor, 1989) are interview-based post operation methods for extracting information from participating personnel. Using these methods we must be aware that in general people are bad at verbalizing their behavior (Woods, 1993). Furthermore, in environments where multiple distributed tasks are performed it can be difficult to recall critical events due to lack of feedback from specific actions and to separate different actions from each other and order them in time (Hoffman et al., 1998). Nevertheless, important information from an operation can be retrieved from participating personnel, though it is resource demanding to acquire.

Table 1: Example of analysis topics and corresponding means of data collection.

		Means of Data Collection	
Topic	*Method*	*Automatic*	*Manual*
Taskforce organisation	*Documentation*	-	*Copy documents*
Operation plan	*Documentation*	-	*Copy documents*
Weather conditions	*Observations and measurements*	*Weather station*	*Observers*
Geographical information	*Access geographical information system used by the staff*	*Database queries, scripts*	*Copy map overlays*
Unit movements	*Position registration*	*Logging GPS*	*Observers*
Casualty treatment	*Timing the flow of casualties*	*Electronic casualty cards*	*Observers, Casualty cards*
Command and Control	*Observation of the staff*	*Video camera*	*Observers*
Command and Control Systems usage	*Log how personnel use system*	*Logging in the system*	*Observers*
Communications	*Radio and telephone recording*	*Digital/Tape recorder*	*Observers*

Table 1 lists several topics of interest in a rescue operation and gives examples of automatic and manual means of collecting data pertaining to each topic. The organisation and initial status of the units forming the taskforce will affect the outcome of the rescue operation and consequently have to be recorded. Additional information about the participants, such as their training status, is also of interest (Morin, Jenvald & Crissey, 2000).

Weather information and the light conditions are other types of information that are relevant and should be recorded regularly. These factors are essential parts of the background information that can help people to create an image of the conditions during the operation, even if they did not participate themselves.

The geographical conditions in the operation area are fundamental in any rescue operation. Geographical information systems (GIS) are becoming increasingly important in rescue operations as they help both first responders and staff members to assess terrain and infrastructure. If a geographical information system is available it can support the visualisation of important aspects of a rescue operation (Jenvald, Thorstensson, Axelsson & Morin, 1999). The use of GIS should also be monitored, and a time stamped log included in the mission history could describe how GIS-information aided command and control during the operation.

When data are recorded from multiple units operating in a large area, it is necessary to use systems and sensors that can record, position-mark and timestamp events and actions automatically. The single most important source of this type of information is the *Global Positioning System* (GPS), which provides both position data and accurate time stamps. If the GPS receiver is connected to other registration equipment it can also be used as a high quality clock or to calibrate the clock in other sensors.

Command-and-control procedures are inherently difficult to register, because deliberations and decision-making are mental processes that are hard to capture (Rouse, Cannon-Bowers & Salas, 1992). Monitoring the communications in and out of the Command Centre provide information both about what information was available at a particular point in time and about what orders were given. Video cameras and observers can add information about the internal working procedures of the command staff (Thorstensson, Axelsson, Morin & Jenvald, 2001). If a command-and-control system is used it can be monitored and the log can provide information on how the system was used with respect to the evolving situation. Post-operative interview methods like the CIT and CDM described above can be used to add information on C2 processes, keeping in mind the limitations of the methods and the resources needed to perform them.

Finally, it is essential to include the *current* plan into the documentation of the operation. After some time plans are revised and a subsequent analyses of an operation must be correlated to the plan that was valid at the time for the operation.

Crucial operational Factors

Several factors affect the outcome of an emergency-response operation. Providing relevant post operational feedback to our responders sets focus on information requirements regarding crucial operational factors. The following list includes some operational factors that can have a decisive effect on the outcome of a rescue operation:

- *Preconditions for the operation*. Organisation of participating units, available resources, existing C2 structures, accessible standard operating procedures, contingency plans, and actual weather are examples of preconditions.
- *Dispatch information*. The first information from the dispatcher contains the initial information about the reported emergency, which is the basis for how the leaders allocate initial resources.
- *Object information*. Available information about the object for the emergency, for example a real estate property or a flat, and time point for accessibility is essential, and when it was used and by whom. Certain objects, for example industrial premises, are controlled regularly and have preplans for different types of situations. Other objects are initially

unknown and responders have to depend on information given by the person who called the alarm. It is also important to relate available information to the actual facts of the object and the evolving operation.

- *Deployment of rescue units*. Initial organisation of units is decisive for achieving a suitable structure for the actual state of the emergency, but it also permits escalation of the unfolding operation.
- *Command and control structure*. An evolving operation can have a dynamic C2 structure. The rescue organisation has an initial C2 structure, but in an escalation this structure can change. How these changes are managed, communicated and perceived in the organisation affects the operational performance.
- *Communication of orders*. Orders reflect decisions, and how they are communicated and perceived is key to efficiency (Shattuck & Woods, 2000).
- *Reports to commanders*. Reports from distributed units form the basis for commanders' situation awareness (SA) (Endsley, 1995) on which all decisions depend.
- *Briefings to subordinated units*. Briefings indicate how the commander influences SA in the organisation.
- *Management of unique and limited resources*. How commanders use unique and limited resources is of utmost importance for the outcome of an operation.
- *Time aspects*. There are three important points of time related to an emergency response operation: (1) the time when the accident or emergency takes place, (2) the time for the alarm dispatch, (3) the time at which the operation is started at the incident scene. There are different measurable time requirements used as tools to shorten the time between 2 and 3, for example, connection requirements for alarm dispatches or time limits for the fire fighters to leave the station. Nevertheless, we should emphasise all aspects from 1 to 3.
- *Inter-agency cooperation*. Operations that involve multiple agencies and disciplines require close collaboration at all levels of command to achieve successful coordinated taskforce response.
- *Escalation of operation*. There are several factors of importance when a dynamically evolving operation is escalated: for example, the definition of breakpoints along approach routes, sectors, assembly points for casualties and goods, establishment of a command post and a medical transportation organisation.

Each of these factors affect the overall taskforce performance and can be matched to possible means of data-collection topics to document operations.

Initial findings at Linköping Fire Department

The opening year of our research project together with the Linköping Fire Department has come to an end and we have learned some lessons. To make the responders aware of the purpose and the goal of the project we conducted an education program for all personnel from the fire department, the police force and the ambulance units working in the Linköping area. It is very important that the responders get the opportunity to ask questions about the data collection and the monitoring of different rescue activities. We have explained how the responders can use the recorded information to improve their future responses to critical incidents. It is a prerequisite for success that the research program is anchored with the concerned personnel.

Our goal is to systematically record a set of measurable parameters using the instrumentation system and to collect additional information and data from various systems that are presently in use. Today we have research equipment following live operations in the Linköping Fire Department. Corner stones in the data collection today are:

1. Recording of the dispatch from the emergency operation centre.

2. Digital recording of communication (Axelsson, 1997) between the rescue commander, team leaders and individual fire fighters.
3. Automatic registration of unit movements with the use of GPS receivers.
4. Digital photographs from the operational use of digital cameras.
5. Video recordings from vehicle mounted cameras.

This data set enables thorough analyses of operations but further development is needed. A substantial amount of communication on the incident scene is performed face to face, not using radio, and some important C2 communication is performed using cellular telephones. Documenting these communications would strengthen analyses. Today we use the MIND instrumentation system design as a flexible research platform, which is quite complex to handle documenting data sources and building mission histories. Our goal is that the responders can operate the instrumentation system without support from engineers and that demands improve system usability. Future developments include:

1. Automatic registration of weather information.
2. Automated compilation of the mission history to support AAR.
3. Pre-definition of a set of standard replays of the mission history.
4. Automated integration of information from support systems handling operations log books, personnel and incident reports.

A goal for the future is that all rescue operations in Linköping Fire Department are evaluated in an AAR with all the responders participating directly after each operation, and that all accumulated data is used for development of tactics and standard operational procedures.

The lessons learned from Linköping demonstrate that adapted methods and techniques for data collection in the field satisfy the requirements for building a mission history from regular rescue operations, performed by an ordinary fire brigade with its present resources. Detailed recording of unit activities, communication and performance reveal shortcomings and mistakes by personnel throughout the organisation. This necessitates thorough information to all personnel about the purpose of this detailed documentation to achieve acceptance and progress for the research project.

Discussion

Our approach has been to build reconstruction ability from the lowest unit level and design data collection tools that fulfil basic operational information requirements. Methods and tools for reconstruction of rescue operations performing well in small-scale routine incidents can be utilised within the framework of larger operations, only in larger numbers. This bottom-up approach enables scaling and adaptation to large-scale special operations with multiple agency emergency response. In everyday routine accidents the basic automated data collection can be the only documentation necessary to provide a basis for subsequent AAR and analyses. Consequent documentation of everyday response over a period of time can reveal systematic issues not noticeable when analysing single events. In special operations resources can be added to collect more information using other methods, for example CIT and CDM described above.

Important issues when recording data from live rescue operations are third person privacy and ethics. Emergency operations are to a large extent related to personal integrity. Rescue personnel are professionals in aiding people in severe traumatic situations, like road accidents or residential fires. Recorded information from these types of operations must be handled with the same ethics and respects as the first responders act themselves, which must be regarded as using this material for research and development.

Summary and conclusions

Documentation, analysis and communication of activities and lessons-learned are important factors of organisational development. These factors are also essential to sustain and improve quality. In this paper we have investigated the requirements of data collection in order to be able to support documentation, analysis and distribution of the lessons learned from rescue operations.
Live rescue operations, performed by a standard fire brigade with basic resources for data collection and analysis, can be successfully documented using adapted methods and tools from the training domain. A basic documentation achieved by automated methods and techniques support detailed after action reviews, subsequent analysis of tactics and standard operational procedures and communication of lessons learned.

References

Axelsson, M. (1997). *Datorstödd tidsmärkt ljudregistrering [Computer-Aided Time-Stamped Sound Recording]*. MSc Thesis, (in Swedish), LiTH-IDA-Ex-97/72, Linköpings Universitet, Linköping, Sweden.

Crissey, M. J., Morin, M, and Jenvald, J. (2001). Computer-Supported Emergency Response Training: Observations from a Field Exercise. In *Proceedings of The 12th International Training and Education Conference, ITEC 2001*, April 24-26, Lille, France.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors, 37*(1), 32-64.

Flanagan, J.C. (1954). The Critical Incident Technique. *Psychological Bulletin*, *51*(1), 327–358.

Fredholm, L. (1996). Decision Making in Fire and Rescue Operations. *Journal of the Fire Service College*, *2*(2).

Gentner, F. C., Cameron, J. A., and Crissey, M. J. (1997). Essential Training Needs and Resources for Simulation Observer/Controllers. In *Proceedings of the 19th Interservice / Industry Training Systems and Education Conference*, pp. 118–129, Orlando, Florida.

Hoffman, R. R., Crandall, B. and Shadbolt, N. (1998). Use of the critical decision method to elicit expert knowledge: A case study in the methodology of cognitive task analysis. *Human Factors*, *40*(2), 254–276.

Jenvald, J. (1999). *Methods and Tools in Computer-Supported Taskforce Training*. PhD Dissertation No. 598, Linköping Studies in Science and Technology, Department of Computer and Information Science, Linköpings Universitet, Linköping, Sweden.

Jenvald, J., and Morin, M. (1998). Tactical Evaluation of New Military Systems using Distributed Modelling and Simulation. In *Proceedings of The 12th European Simulation Multiconference*, June 16-19, Manchester, UK.

Jenvald, J., Rejnus, L., Morin, M., and Thorstensson, M. (1998). *Computer-Supported Assessment of Emergency Planning for Rescue Operations*. User report FOA-R--98-00910-505--SE, Defence Research Establishment, Linköping, Sweden.

Jenvald, J., Thorstensson, M., Axelsson, M., and Morin, M. (1999). GIS Supporting Collaborative Mission Training for Rescue Operations in Hazardous Environments. In *Proceedings of The 2nd Conference on The Applications of Remote Sensing and GIS for Disaster Management*, January 19-21, Washington DC, USA. Available as FOA-R--99-01042-505--SE.

Jenvald, J., Morin, M, and Rejnus, L. (2000). Developing Digital Courseware from Multimedia Documentation of Full-Scale Chemical Exercises. In *Proceedings of The NBC 2000 Symposium on Nuclear, Biological and Chemical Threats in the 21st Century*, June 13-15, Espoo, Finland.

Jenvald, J., Morin, M., and Kincaid, J.P. (2001a). A Framework for Web-Based Dissemination of Models and Lessons Learned from Emergency-Response Exercises and Operations. *International Journal of Emergency Management*, *1*(1), 82–94.

Jenvald, J., Johansson, B., Nygren, A. and Palmgren, S. (2001b). Empowering the Responders to Learn From Real Incidents: A Swedish Research Initiative. In *Proceedings of The International Emergency Management Society´s Eighth Annual Conference, TIEMS'2001*. June 19-22, Oslo, Norway. Available as FOI-S--0075--SE.

Klein, G. A., Calderwood, R. and MacGregor, D. (1989). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man, and Cybernetics*, *19*(3), 462–472.

Lederman, L. C. (1992). Debriefing: toward a systematic assessment of theory and practice. *Simulation & Gaming, 23*(2), 145-160.

Morin, M. (2001). MIND—Methods and Tools for Visualization of Rescue Operations. In *Proceedings of The International Emergency Management Society´s Eighth Annual Conference, TIEMS'2001*. June 19-22, Oslo, Norway. Available as FOI-S--0077--SE.

Morin, M., Jenvald, J., and Worm, A. (1998). Training Emergency Management and Response: Creating the Big Picture. In *Proceedings of The International Emergency Management Society´s Fifth Annual Conference - TIEMS´98*, May 19-22, Washington DC, USA.

Morin, M., Jenvald, J. and Thorstensson, M. (2000a). Computer-Supported Visualisation of Rescue Operations, *Safety Science*, *35*(1–3), 3–27.

Morin, M., Jenvald, J. and Crissey, M. J. (2000b). Training Needs and Training Opportunities for Emergency Response to Mass-Casualty Incidents. In *Proceedings of the 11th International Training and Education Conference, ITEC'2000*, pp. 386-399, The Hague, The Netherlands.

Morrison, J. E. and Meliza, L. L. (1999). *Foundations of the After Action Review Process*. Special Report 42. United States Army Research Institute for the Behavioral and Social Sciences.

Murray, B. (1994). Training for operational command. *Fire Professional*, Autumn, 67–71.

Rankin, W. J., Gentner, F. C. and Crissey, M. J. (1995). After Action Review and Debriefing Methods: Technique and Technology. In *Proceedings of The 17th Interservice/ Industry Training Systems and Education Conference*, Albuquerque, New Mexico, USA.

Raths, J. (1987). Enhancing Understanding Through Debriefing. *Educational Leadership*, *45*(2), 24–27.

Rouse, W. B., Cannon-Bowers, J. A. and Salas, E. (1992). The role of mental models in team performance in complex systems. *IEEE Transactions on Systems, Man and Cybernetics, 22*(6), 1296-1308.

Rejnus, L., Jenvald, J. and Morin, M. (1998). Assessment of Emergency Planning Based on Analysis of Empirical Data. In *Proceedings of The Sixth International Symposium on Protection against Chemical and Biological Warfare Agents (CBWPS)*. May 10-15, Stockholm, Sweden, 377–383.

Salas, E., Dickinson, T. L., Converse, S.A . and Tannenbaum, S. I. (Eds.) (1992). *Toward an understanding of team performance and training.* Norwood, NJ: Ablex.

Shattuck, L. G. and Woods, D. D. (2000). Communication of intent in military command and control systems. In McCann and Pigeau (Eds.) *The Human in Command: Exploring the Military Experience*. Kluwer Academic/Plenum Publishers, New York.

Thorstensson, M. (1997). *Structured Reports for Manual Observations in Team Training.* MSc Thesis LiTH-IDA-Ex-97/64, Linköpings Universitet, Linköping, Sweden.

Thorstensson, M., Morin, M. and Jenvald, J. (1999). Extending a Battle Training Instrumentation System to Support Emergency Response Training. In *Proceedings of The 10th International Training and Education Conference (ITEC99)*, April 13-5, The Hague, The Netherlands. Available as FOA-R--99-01141-505--SE.

Thorstensson, M., Axelsson, A., Morin, M. and Jenvald, J. (2001a). Monitoring and Analysis of Command-Post Communication in Rescue Operations, *Safety Science, 39*(1-2), 51–60.

Thorstensson, M., Tingland, B., Björneberg, A. and Tirmén-Carelius, M. (2001b). Visualization of an Interagency Exercise in the Stockholm Underground. In Proceedings of *The International Emergency Management Society´s Eighth Annual Conference*, *TIEMS'2001*. June 19-22, Oslo, Norway. Available as FOI-S--0076--SE.

Woods, D. D. (1993). Process-tracing methods for the study of cognition outside of the experimental psychology laboratory. In Klein, G. A., Orasanu, J., Calderwood, R. and Zsambok C. E. (Eds.), *Decision making in action: Models and methods*, pp. 228-251, Norwood, New Jersey: Ablex.

Acknowledgment

This work was sponsored by the Swedish Rescue Services Agency (SRV).

Special acknowledgment to Linköping Fire Department and their Deputy Fire Chief Anders Nygren for help and support in our research.

Author Biography

Mirko Thorstensson holds a MSc in Mechanical Engineering from Linköping University and is currently a PhD candidate at Linköping University. Mr. Thorstensson is a member of the MIND research group at the Swedish Defence Research Agency (FOI), where he is project manager and responsible for structured reports for manual observations. His research interests include knowledge acquisition, structured reports, simulation and registration systems. Mr. Thorstensson is a Lieutenant in the Swedish Army (res.) and a member of the Swedish Defence Science Society.