

# Taxonomy of IT support for training emergency response & management

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## ABSTRACT

Training is a prerequisite for effective and efficient emergency response and management. Information technology (IT) offers high potential to support various educational methods and environments. One example for interdependent use cases is given by planning, controlling, observation and debriefing of training exercises. Dedicated IT systems are available to support these use cases; nevertheless, there is no joint understanding of system use cases, types and functionality as a fundament for scientific and technological progress. This work in progress paper presents results of literature and market research complemented by expert interviews leading to a taxonomy of relevant IT components and systems.

## Keywords

emergency preparedness, taxonomy, learning management, training support, exercise, emergency response

## INTRODUCTION

Learning for workaday-scenarios is a fundamental preparation for large-scale disasters (cp. Borell and Eriksson, 2013). Building on theoretical fundamentals taught in lectures and classroom environments, training in exercises with realistic scenarios is essential to gather experiences (NN, 2012). To reach this goal, trainers need to solve challenges in designing scenarios and to apply them for learning purposes (cp. Schank, 1993). This includes the explicit reflection of experiences from exercises. Training environments of different scales are used to introduce trainees physically into realistic scenarios; they are equipped with various types of a) actuators to present scenarios and b) sensors to measure response activities. Technological progress towards smaller, cheaper and more efficient devices increases the applicability of new installations. In addition, software becomes more and more capable to support trainers in planning, controlling, observing and debriefing exercises significantly. The integration of these components and systems is essential for a holistic approach although this means significant changes for training processes. Usability is a key criterion due to high complexity, media variety and information overload. Technological evolutions and best practices need to be shared to facilitate an optimal contribution to crisis management. A taxonomy of IT systems in this field helps to create comparability supporting identification, selection and procurement processes, to set reference systems and make them visible to communities, to strengthen a dedicated market, to build a research community able to share and compare results and to specify a reference architecture preparing for interoperability on all levels and for all processes.

This paper aggregates results of different studies<sup>1</sup> with regard to the domain, involved stakeholders, their tasks and environments and the state-of-the-art in supporting IT solutions. Based on these building blocks, the taxonomy is presented as an aggregation of needs (i. e., domain analysis results) and opportunities (i. e., available technology). The paper presents an outlook to future research work as well as open challenges.

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**METHODOLOGY**

This paper is based on literature research, a series of semi-structured interviews with trainers at different emergency response and management organisations and corresponding training institutions, and non-participating observations of exercises. The results were interpreted from different perspectives:

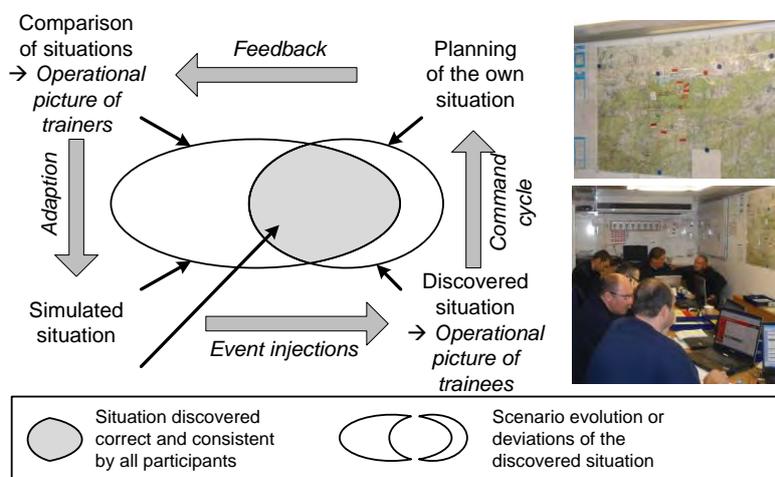
- Stakeholder and context analysis: Interviews and observations are used to validate literature analysis results, to identify specific tasks besides legislative texts (e. g., defined to cope with a lack of resources) and to interpret practical roles. These steps allow to derive roles and tasks and to describe their context.
- Use case analysis: Special focus is set to information flow and the a) usage of knowledge and b) creation of new knowledge. While some information is specified in general, this analysis is based on the interviews.
- Technology study: For research publications, this paper is based on a keyword-based analysis of ISCRAM papers being the most comprehensive international conference series in this domain. For commercial solutions, candidates were selected based on the visibility for potential customers; these systems are enriched by demonstrators from research projects in the German and the European security research programs.
- Complementary research on taxonomies or classification schemes for information systems: literature from Information Systems Research (e. g., Gluchowski, Gabriel and Dittmar, 2008) and taxonomy concepts (e.g. McLean, Jain and Lee, 2008; Nickerson Muntermann and Varshney, 2010) are used to prepare the design approach for a taxonomy of information systems for training emergency response and management.

**TRAINING EMERGENCY RESPONSE & MANAGEMENT**

Training exercises are scalable regarding size (i. e., number of participants, spatial dimensions) and complexity (i. e., the emergency scenario and their interdependence with the actions of participants). As an example, exercises to train ‘Zugführer’ (‘C level commanders’) involve up to four fire engines and 20 fire fighters. The roles in an exercise can be divided into trainers (i. e., teachers or coaches), trainees (i. e., learners), assistants (like IT administrators) and actors (playing roles like affected citizens). Trainers are in charge of the exercise control. Besides trainers, this includes observers (taking notes and gathering data) and referees (focusing on critical situations). Trainees are structured as heterogenous or homogenous groups interacting in the exercise environment. In some cases, trainees need to learn individually without group interactions.

Training structures and processes need to be adapted to the background of trainees. Both for professional as well as for volunteer staff, standards are defined regarding educational levels. Careers include step-by-step courses complemented by operational experience in real incidents. Thus the complete learning process in this context is based on a combination of common as well as specialist basic knowledge, in training units gained action-taken know-how and experience based competency. This paper focuses on exercises which are part of these courses.

For trainers, exercises comprise four phases: planning, control, observation and debriefing (cp. Department of Homeland Security, 2004). In all activities they have to maintain a model of the current situation, identify the status perceived by the trainees and its difference to the actual situation, plan the evolution of the exercise in a learning-oriented way as well as inject scenario events to stimulate actions and decisions (see Figure 1).



**Figure 1. Comparison of operational pictures for exercise control (Pottebaum, Marterer and Koch, 2013)**

Often following a constructivist approach, the creation of scenarios (i. e., an evolving simulated situation) and the reflection of individual experiences are essential; improvisation skills are needed to design complex scenarios towards the intended learning goal (Mendonça and Fiedrich, 2006). Emergency situations are re-enacted in order to mediate experience based knowledge as realistic as possible. Exercise artificialities (e. g., time leaps, insufficient contact with real dangers and emotional relations to trainers) cannot be eliminated. After an exercise, logs are an important tool for reflection in debriefings and post learning units (Pottebaum, 2012). To determine the difference between the re-enacted situation and the actual situation recorded by the participants a comparable representation (in terms of an ‘operational picture’) of both is needed. Having trainers and observers in the field, the subjective influence of their situation capture has to be considered.

## **IT SUPPORT (FOR TRAINING EMERGENCY RESPONSE & MANAGEMENT) – RELATED WORK**

IT needs to enable the mapping of a variety of coherences between exercise elements (cp. Figure 1). Moreover, dynamic temporal processes need to be computed in a realistic and expedient way by respective means. IT needs to facilitate scenario event injections and to allow the interaction between stakeholders and elements of the exercise. Thus the uncertainty and indeterminacy of an emergency situation can be provided by means of a flexible variation of the exercise conditions. Moreover, IT should simplify scientific observation including the ‘ability to record the observation’ (see Greve and Wentura, 1997). Technological support should cover an automatized recording and processing of different data types. Virtual training environments provide fully immersive IT solutions for exercises; physical training environments are equipped with various other IT systems. They allow for the management of scenarios (i. e., pre-defined sets of events) and corresponding event injections (German: „Einlagen“) for an executive staff during an exercise or generate complete 3D visualisations of scenarios. These IT systems provide functionalities supporting the four phases described above.

### **Exercise planning and control**

Training exercises in physical environments can be controlled by hardware actuators like artificial smoke, flash-over simulators and realistic sounds. Remote-controlled puppets and flooding can be part of a scenario. Such devices can be controlled from a central control room and partially by mobile devices like tablet computers. The user interface of such IT systems allows for the definition of scenario steps on a timeline. Predefined scenarios can be selected and activated. Individual changes during runtime of an exercise are possible. (Olbring, 2008)

Executive staff trainings demand for another kind of IT systems. One possibility is to integrate simulation tools for operation control into C2 systems. Those normally include a component for communication via (form-based) messages, which are used by an executive staff for information exchange with its environment. Simulation is used for scenario event injections and for sending these events to the trainees. An extension of this class is represented by the system PRO DV deNIS II<sup>USA</sup> (Möws, 2008). It adds functionality for an explicit event injection management and documentation as well as analysis functionality. Beyond that, there are several IT systems which provide (3D) visualisation of scenarios (e. g., e-semble ISEE and XVR Crisis Media).

### **Technical observation, exercise analysis and debriefing**

The logging can be performed in an unstructured (notes in undefined shape), semi-structured (e. g., in schedules) or structured way. Journals, representing the series of events that occurred during a training exercise (cp. Mendonça and Fiedrich, 2006, Turoff, Chumer, van de Walle and Yao, 2004), in combination with videos, can be used as a basis for real-time scenario adaptations in terms of exercise control and for debriefing. Some commercial IT systems allow for editing the operation log subsequently and transferring it into scenarios, which can again be presented in integrated simulation components (e. g., Intergraph Planning & Response and the project OASIS as an outstanding example with explicit functionality for the acquisition of ‘lessons learned’).

Data (like audio, video, GPS and manually logged events) from planning, control and technical observation can be used for analytical purposes (e. g., statistical methods, visual analytics or dashboard and/or timeline visualisations). Some patterns in an exercise can be detected automatically, others become obvious to trainers through visualisations. Cameras from different perspectives and complete data streams tagged with relevant timestamps allow for more sophisticated after-action-reviews in comparison to paper-based notes as used today. Valuable insights can be gathered from behavioural research, professional sports and usability labs.

### **Authoring and learning management**

Most Learning Management Systems (LMS) are designed as web based platforms comprising presentation of content, authoring of tests and exercises, evaluation and rating support, administration and communication tools (cp. Baumgartner, Häfele and Maier-Häfele, 2004). They are often extended by authoring systems like Microsoft PowerPoint or Adobe Dreamweaver (in that case sometimes called Learning Content Management

Systems/LCMS). Content is stored as Learning Objects (LO) representing the smallest self-contained course information; in case these LOs are complemented by meta data and stored in standard formats, they are called RLOs (Reusable LO) (Baumgartner et al., 2004). Many stakeholders in emergency response and management deploy LMS in their education environments (for instance, see the 'e-learning portal' of the German THW). As training exercises are embedded in educational programmes, LMS are part of the technological context. Tools for the creation of scenarios can be categorised as authoring tools for specific applications.

### Simulation

Simulations can be distinguished either with regard to the simulated objects or with regard to use cases. A categorisation according to the objects to be simulated is given in (Jain and McLean, 2005) including systems simulating social behaviour (e.g., crowd movement), physical phenomena (e.g., fire propagation), environmental characteristics (e.g., weather), organisational aspects (e.g., processes) and infrastructure system issues (e.g., water supply). Alternatively, simulations can be categorised with regard to training support systems:

- Simulations directly supporting emergency response (e. g., as a forecast tool). The respective simulation systems are provided to the trainees as well as to the trainers.
- Simulations supporting planning and controlling exercises (Dugdale, Bellamine-Ben Saoud, Pavard and Pallamin, 2009). Trainers are supported in terms of realistic background information and situation forecasts.
- Simulations directly supporting immersion of trainees in a scenario (cp. projects like SAFER and V-SICMA).

Computer based simulations can also support trainers in modelling a realistic scenario by testing alternative evolutions. Simulations support the trainers in managing the training situation by reducing the complexity of their mental model about it and calculating dynamic evolutions of boundary conditions.

### TAXONOMY OF IT SUPPORT FOR TRAINING EXERCISES

Both on the demand side and the supply side described in the previous sections, several concepts can be used to categorize use cases, components and systems. Complementary to that, established terminology is taken into account: Firstly, many of the identified use cases correlate to management support systems; secondly, these IT systems should be integrated with software (like C2 systems) used by trainees both in operations and exercises (cp. Turoff et al., 2004). Therefore, the following taxonomy is based on a multi-perspective approach.

The taxonomy focuses on support for trainers; partially this includes approaches to substitute trainers by intelligent software components (cp. serious gaming (GAM)). On an abstract level, this is compliant to the taxonomy of management support systems subsuming management information systems (MIS), decision support systems (DSS) and executive information/support systems (EIS/ESS). This paper proposes to introduce the term **Exercise Support Systems (XSS)** for training emergency response and management.

Starting with this high level extract of the taxonomy, the sub-ordinated concept can be extended by their components. The IT systems identified in the previous section are analysed and transferred into system and component categories subsuming various sub-types and characteristics.

- **Exercise Planning Support Systems (XPSS)** include Authoring Systems (AS) for effective and efficient learning content creation (including definition of scenarios and to-be events) and LMS/LCMS for all information management tasks. Simulation (SIM) can be used to identify 'optimal' scenarios.
- **Exercise Control Support Systems (XCSS)** are built based on Exercise Control Systems (ECS) like PRO DV deNIS IIUSA and Simulation components (SIM) to provide decision support. Interfaces to Observation Support Systems (OSS) are needed for interactive and flexible adaptations of exercises.
- **Exercise Observation Support Systems (XOSS)** are based on Sensor Data Processing (SDP) and Observation Support Systems (OSS). This includes technical (automatic) and manual data acquisition and requires corresponding communication networks and middleware.
- **Exercise Debriefing Support Systems (XDSS)** include software for the analysis of behavioural data (data analysis real-time and ex-post, i. e., DA-RT/-EP) accessing data from Training Data Management (TDM) and aggregating information in Debriefing Support Tools (DST).

Further systems need to be taken into account but are not addressed explicitly in this section; for instance, this applies for Geographical Information Systems (GIS), Enterprise Content Management Systems (ECMS), Emergency Operation Control Systems (EOC) and Command and Control (C2) solutions.

## CONCLUSION

This paper presents a taxonomy of IT systems supporting training for emergency response and management. It is based on a thorough analysis of available commercial IT systems, demonstrators and concepts from research projects and use cases derived from stakeholder and context analysis. The taxonomy proposes a phase-driven approach detailed by functional divisions of systems and components. It will add value to various research activities. As an example, the field of data exchange and standardization will benefit from the bridges between operational uses cases and training exercise as well as the deep understanding of the domain. Especially information flow and requirements need to be analysed consistently; the taxonomy will help to setup an established framework. The opportunities of IT support for exercises in physical environments (in contrast to virtual environment) are rarely researched; therefore the taxonomy helps to transfer research results and to check their validity. Moreover, the taxonomy can be used to discuss usability criteria for exercise data presented to trainers and trainees in debriefing sessions.

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