Psychological Requirements for Crisis and Emergency Decision-Support Systems for Public Transport Control Centers

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ABSTRACT

Control center staff is used to working with software applications for e.g. surveillance of production processes, for controlling and timing of industrial logistics, and for recording and filing incidents and actions. Yet, decision-support systems for emergency situations pose additional demands on employees in this domain.

This paper reports first findings for psychological requirements for decision support systems in the rise of emergencies as identified in a federal German research project in the domain of public transportation. In control centers both the humans on duty who have to intervene during an emergency, and the technical system which provides decision-alternatives for supporting the action are considered. Based on findings of the project, psychological, technical and organizational requirements identified in interviews, observations, document analysis and additional relevant literature are generalized.

Keywords

Requirements analysis, decision-making, crisis management, control center, public transportation, control room.

DEVELOPING USER-CENTERED EMERGENCY DECISION-SUPPORT SYSTEMS FOR PUBLIC TRANSPORT CONTROL CENTER STAFF

Decision support systems are usually developed for supporting and improving managerial and organizational decision-making (Arnott and Pervan, 2008; Power and Sharda, 2007). This "digital support" by IT based systems presents complex information in a way that minimizes mental workload and maximizes comprehensibility. For example, for a profit prognosis, data are selected, analyzed and prepared for presentation, thus improving process and outcome of decision-making (Arnott, 2004).

Emergency situations are usually not encountered on a daily basis in the workplace environment of public transport control centers. Thus, a crisis and emergency decision-making support system will have to meet not only the situational requirements of the incident, but also the cognitive requirements of the staff (Zinke, Hofinger and Strohschneider, 2010). If such systems are designed adequately, even very complex scenarios could potentially be solved faster and more efficiently (Nokhbatolfoghahaayee, Menhaj and Shafiee, 2010).

There are numerous studies concerning control rooms in different domains, e.g. electrical power industry (cf. (Klashner and Sabet, 2007)), and air traffic control (cf. Leal de Matos and Powell, 2003). However, little literature is available dealing with crisis management in control rooms, especially in the domain of rail transportations systems. There are findings with focus on human factors and technology in rail systems, usually investigating ergonomic questions, e.g. signaling or control room layout (e.g., Wilson and Norris, 2006; Heath and Luff, 1992). So far no connection has been made between crisis management and psychological requirements for control room staff. This paper is a contribution to bridging this gap.

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In a security research project reported in this paper, possibilities for a crisis and emergency decision-making support system (CEDSS) for public transportation control centers are investigated. Here the need for decision-making support is usually limited to ad-hoc, short-term (operative) decisions and action. Yet in an emergency control center staff also has to make tactic decisions influencing forthcoming processes. One example is the declaration of an emergency which activates the crisis management team and evokes the company's response-structures for such events.

METHOD

The research project

In the joint research project OrGaMIR, funded by the German Federal Ministry for Education and Research, one of the aims is to investigate a software solution which supports the control center staff's decision-making in emergencies and crisis. The project concentrates on the domain of public transportation, where emergencies potentially affect large numbers of passengers. The German acronym OrGaMIR stands for "Cross-organizational hazard prevention to protect human life and critical infrastructures by optimized prevention and reaction".

The project focuses on crisis management in major incidents involving fire, smoke, and toxic substances. The goal is an integrated system for evaluating the present and expected contamination of underground systems with hazardous substances by means of substance detection and analysis, the calculation of the propagation, and the targeted dissemination of consolidated, context-sensitive information. The OrGaMIR system provides support by suggesting options for action for different management levels within the public transport company. This would enable all stakeholders involved to make decisions on a more reliable basis. Information processing within the decision-support system has been reached, while the GUI mock-up is still work in progress.

The development of the system is complemented by the consistent integration of human factors, such as information processing and decision-making under stress. The authors analyzed requirements of decision-making in emergencies and crisis, characteristics of individual actions in critical situations in the domain of public transportation, and the control center staff's informational needs when using the CEDSS.

Data

In this explorative study, qualitative research methods were used. Although the project cooperates mainly with one transportation company (company A), data was also collected from four other German public transportation companies running underground railway systems. Thus, the specific organizational structures and procedures of company A could be taken into account, as well as general requirements of crisis management in underground transportation. The analysis combined document analysis, interviews, and observations. Insights were obtained in emergency procedures, plans for crisis management, and behavior in emergency exercises.

First, relevant documents of company A concerning emergencies and crisis management were examined by means of document analysis (Mayring, 2002). The processes and procedures for emergencies and crisis were then structured as flow-charts for the procedures for several types of events (incident, emergency, crisis and catastrophe). The results were compared with the documents from three further companies (company B to D), to consolidate the knowledge about the nominal reporting channels and flow of information, etc. Based on this knowledge, nine semi-structured expert interviews (Flick, 2007) were conducted within company A. Depending on the time of day, two to five operators usually work in each control room shift. Experts were defined by their employment in control rooms and /or their position within the crisis management department within the public transport company; most of them had served as control center staff. Each interview lasted from between one to three hours. All interviewees were additionally observed in their regular work environment for a short period of time. The focus of observation was to identify reoccurring tasks, their frequency, and the use of computer aid (online visualization of train movements, charts, maps, etc.). Each interview was transcribed and later analyzed for a comparison of the demands put on staff. Besides workplace non-participant observations (Lamnek, 2005) in company A, additional observations in three further control centers allowed insights into normal working conditions. The control center staff's knowledge of critical situations was explored by short additional interviews in companies B to D.

In order to describe individual action requirements in critical situations, one focus of the analysis was to investigate work and role-specific requirements for action by "average" control center personnel in public transportation. These requirements, derived from company A to D, are summarized as a prototypical "control center staff role" further below. The analysis of data is still in progress. Despite this, specific psychological constraints of control center staff in emergencies and crisis could already be identified. Also, first results from observations and interviews with staff testing a mock-up version of OrGaMIR are included which go beyond aspects of usability.

CHARACTERISTICS OF CRISIS, AND PSYCHOLOGICAL REQUIREMENTS FOR CONTROL CENTER STAFF

The routine tasks of staff in the control room included mainly services for passengers: supervision and ensuring of the scheduled movements of underground trains, reacting to delays by informing passengers about alternate routes, and responding to passengers using the combined stationary SOS-/ information telephone. In order to understand why emergencies and crisis may challenge control-center staff, characteristics of crisis from a psychological point of view are summarized from the literature. In table 1, important aspects of crisis are outlined together with the psychological consequences for the responding individual.

General characteristics of crisis	**Psychological consequences**
Threat to life, health, the environment, or other important goods	▪ urgent need of action and the importance of decision-making increase the level of stress ▪ anticipated consequences of wrong decisions load additional stress (Zinke, Hofinger and Strohschneider, 2010)
Stress and anxiety	▪ limiting the individual´s cognitive capabilities, in consequence fostering suboptimal decision-making (Dörner, 1996) ▪ threat to feeling of competence (Lazarus)
Uniqueness of situation	▪ need for active analysis of available information and generate alternatives for problem solving an decision-making ▪ Ambiguity leads to loss of shared meaning, as well as to the shattering of commonly held beliefs (Dörner and Schaub, 1994)
high dynamics and load of information	▪ perceived lack of action control adding to stress level (Langer, 1983) ▪ time pressure for decision-making on inadequate basis of information ▪ lack of information contradicts human need of control (uncertainty)

Table 1: General characteristics of crisis and psychological consequences

In order to explain basic psychological requirements of crisis situations, it is necessary to look at different scenarios. Public transportation companies differentiate between incident, emergency, crisis and catastrophe, with a decreasing likeliness and increasing effect. This classification of non-standard events was used to specify requirements for action. In a second step it was used to differentiate possible psychological constraints as well as cognitive and behavioral requirements staff has to meet. In the analysis, categories were defined to specify roles and procedures reported for normal operations and minor incidents. In a second step these were contrasted to those in emergencies or crises. As the project focuses on fire and gas incidents, these were used as scenarios in the interviews. The aim was to identify psychological requirements and specific skills needed for an adequate response. Here, the findings for control center staff are reported (table 2).

For control center staff, standard processes and rules for behavior in emergency and crisis existed in all of the companies (A to D). In the literature a number of similar tasks were identified (e.g., Yoon, Velasquez, Partridge and Nof, 2008). Table 2 lists responsibilities, required skills, and expected behavior (according to rules and regulations of the transportation companies). Additionally, observations by the authors during routine operations, potential psychological sources of employee behavioral deviance and the psychological constraints are given. The regular tasks of control center personnel were found to be quite similar in companies A to D, the requirements can be considered as derived from an average role. Yet, due to a small sample, the set of requirements is not to be considered complete.

A first conclusion from a psychological perspective is that control center staff in an emergency or crisis has to deal with unfamiliar procedures while being troubled by camera impressions from the events on site. These events put emotional and sometimes ethical burdens on those dealing with the situation while at the same time being required to make quick decisions. As crisis management is not their daily business, control center personnel in such a situation may profit from decision-making support systems. Given the low frequency of these events, additional software for this purpose is likely to remain unfamiliar and therefore might not be used adequately. Thus, decision-support systems need to meet specific (psychological) requirements with respect to usability in order to be accepted, considered reliable (trust), and used.

REQUIREMENTS FOR CEDSS: USERS' AND PSYCHOLOGISTS' PERSPECTIVE

Emergency and Crisis Decision Support Systems (CEDSS) are tools that offer a limited number of options for action in a given situation. The CEDSS investigated in OrGaMIR offers specific options for different roles in the

control center aligned with given tasks and responsibilities. First user tests revealed the users' perspective on system requirements. Some of the preliminary results are given here.

	Control center staff
Responsibilities	▪ coordination of internal and external communication ▪ mediate inquiries (e.g. from passengers or emergency services on site) ▪ assign categories or procedures provided by the IT-System /CEDSS
Required skills	▪ accept and handle responsibility ▪ identify relevant stakeholders ▪ talk to persons from other organizations ▪ make appropriate loudspeaker announcements to passengers
Expected behavior	▪ aggregate and refine information ▪ make quick and efficient decisions ▪ distribute selected information according to event-specific procedures ▪ anticipate the development and scope of the event with regards to the stakeholders to be informed and their priorities ▪ act according to the standards operation procedures without own judgment
Observations of problematic behavior	▪ staff don't know whom they have to inform ▪ conflicting procedures cause uncertainty and delay ▪ insufficient or incomplete information is delivered ▪ overlapping responsibilities slow down fighting an emergency or crisis
Potential sources of employee deviance	▪ technical limitations: possibility of technical systems/ software to exchange status reports with internal and external stakeholders ▪ SOPs inappropriate for the situation, force staff to deviate from rules ▪ unclear responsibilities result in loss of information or in redundant or insufficiently filtered information ▪ need to process large amounts of quickly incoming data in an emergency
Psychological constraints	▪ being used to daily routines may hinder action according to unfamiliar non-routine procedures ▪ decision-making may be influenced by fear to make mistakes ▪ sight of wounded and dead from the surveillance cameras without being able to respond on site may arouses feeling of helplessness ▪ false alarms may weaken quick response in an emergency

Table 2: Role-specific requirements for control center staff, behavior, and constraints in emergency and crisis, observed in German public transportation companies.

Each person in a control center has to accomplish a specific list of pre-defined tasks in the case of an emergency according to their role. The CEDSS task list was considered by control center staff to be helpful in facilitating decision-making. To facilitate decision-making further, results of actions and status of tasks (accomplished or open) should also be displayed. Because not all tasks necessary in responding to a crisis situation can be considered in advance, it should be possible to add tasks to the list later on. The OrGaMIR system provides rescue options for passengers in the subway station affected by the incident. Safe exit routes and contaminated areas are displayed on control center screens. In the user test, the GUI displayed alternating the contaminated subway escape routes or the normal subway map. Users mentioned difficulties in recognizing contaminated escape routes on the normal map after the map showing contaminated areas had vanished. Therefore, a CEDSS should constantly present the most important information during the entire process of crisis management.

Nowadays, control centers are provided with software solutions for all operations. The users find it important that a crisis and emergency decision support system should not be an isolated application but rather an integrated add-on for the familiar existing systems. For example, different map formats should be avoided as control center staff in the test needed a longer period of time to identify information on new maps. At the onset of a crisis in particular, map scaling should display the whole subway station in bird-eye view to provide an overview of the affected area. In the course of action, control center staff needs basic situation-specific information, e.g. number of passengers in the subway station, site of operation, size of affected area. If this information is not given comprehensively by the CEDSS, the control center staff said they would gather this key information elsewhere. If the system provides key information, it is considered reliable by the users.

Additional information should be available on demand but not presented permanently in order to prevent information overload, e.g. the area surrounding a subway station. Important information or warnings should be highlighted and immediately attract attention, e.g. by the use of flashing, bold print or signal tones. Highlighting of information should be used only for the most important pieces of information and should not be used for elements displayed permanently.

Another aspect is the use of colors in display information. Colors can be used to represent certain conditions of the system concerning the actual situation, e.g. display affected areas on the subway platform (Künzer, Zinke and Hofinger, 2010). Colors should be used with high contrast and in an intuitive way without ambiguity, e.g. accessible exit routes for passengers should be displayed in green color. Captions are helpful to clear intended meanings, not only for colors used but also for soft keys (buttons) and symbols.

CONSEQUENCES AND CONCLUSIONS

Even if usability and ergonomic aspects are well considered, software solutions which support decision-making in public-transport control centers have to face structures and guiding principles of the public transport organizations. Organizational contexts define the conditions under which individuals will act, also based on their "best-practice" experiences. To enhance decision-making on the basis of a CEDSS, psychological requirements have to be considered, too. Technical systems should contribute to minimize mental workload, reduce complexity and, by meeting these criteria alike, offer real support.

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