TRAIN TRAFFIC CONTROLLER'S TASK DEMANDS DURING A MAJOR RAILROAD CONSTRUCTION WORK

Marja-Leena Haavisto, Kaarin Ruuhilehto and Pia Oedewald
Technical Research Centre of Finland, P.O.Box 1000, FI-02044 VTT, Finland
marja-leena.haavisto@vtt.fi

ABSTRACT: The aims of this study were to analyse the cognitive demands of the train traffic controller's task and to evaluate organisational support for performing their task safely during railroad construction work. The cognitive task analysis (CTA) and analysis of situation awareness (SA) requirements were conducted to elicit the cognitive demands placed on of the controllers during their work. A total of six train traffic controllers, three novices and three experts, participated in the field study. Ten others, representing regulators, supervisors and planning engineers were also interviewed as part of the study. Granting permission for railroad work includes six separate phases which are not completely sequential. The SA analysis indicated that at least twelve elements are critical for maintaining SA during the monitoring and controlling of train traffic and railroad work. The safety culture model utilised in study allowed several considerable changes to be identified, e.g. in organisational responsibilities, regulations and work instructions.

1 INTRODUCTION

In recent years, large railroad work projects have been started in Finland to upgrade the capacity of line sections. The train traffic controlling is a critical function when managing safe and efficient use of the track during extensive railroad work. The traffic controllers are responsible for allocating and assigning track use and granting permissions and notices required for train traffic. In addition, they are responsible for protecting the railway work areas, granting permission for railway work and receiving information on the completion of such work. Furthermore, they also inform passengers about exceptional circumstances in rail services through announcements and station display boards. This study focused on the task demands of train traffic controllers and analysed the support available for these demands from the organisational functions.

Train traffic control centres are complex dynamic work environments with many interactions between different parties e.g. the railroad subcontractors, stations, and train drivers. The pace of events that controllers have to follow up (e.g. [1]) is externally determined. The sequences and demands of these dynamic tasks are not easy to depict, train and change [2]. While the tasks are complex and the main activities are not physical, it is important to analyse the controller's cognitive activities i.e. how they think, what they know, how they organise and structure information, what information they seek and where they seek this information. Cognitive task analysis (CTA) methods [3] focus upon describing and representing the cognitive elements that underlie visible behaviour. In the work environment the analysis is focused on complex cognitive systems which involve the knowledge and reasoning of individuals, but also people interacting with each other via computers in the networks of humans and technology, working as a member a team and working as a part of an organisation [2]. The results of the CTA can be applied to many areas, including equipment design, task design, environmental design, and the training and selection of new workers [4].

In complex and dynamic railroad environments, decision making is highly dependent on situation awareness (SA) – what is happening around you and understanding what that information means to you now and in the future [5, 6]. Furthermore, effective performance depends on shared knowledge and situation awareness between the team members and co-workers in the railroad operations [7]. Situation awareness is based on situation assessment which refers to a process of constructing an explanation to account for one's observations of elements in a dynamic situation [1].

The work environment and the technology should support the demands of the task, in this case, for example the formation of SA and decision making [5]. If the critical information is not available for traffic controller at the right moment, he/she has very difficult to maintain accurate SA in working memory during traffic situations. The perception of time and the temporal dynamics of the situation are critical to understanding when the required action must be taken. The other critical temporal aspect is to understand the rate which the situation is changing. Some of the restrictions are related to the limitations of the human cognitive system, like focusing attention on only one target at time and the time it takes to switch attention from one information source to the other.

This study adopted a socio-technical system safety approach to examine how the organisational functions support the safety-critical work of train traffic controllers. According to Rasmussen, a multi-level model of socio-technical system [8] includes several levels of actors: governmental laws, national regulators, company and management levels and finally team and individual actor levels. All the levels affect human performance in the human-machine system.

Reiman and Oedewald [9] have developed a safety culture model that includes organisational processes or functions that can affect the personnel's safety-conscious behaviour and ensure safe performance. The model and the contents of each organisational function is presented in the method section (Fig. 2). Organisational functions represent critical areas that safety critical organisations should take into account when developing high levels of system safety. These functions have both direct and indirect influences on the way daily work activities are carried out. Thus the model was used as a framework for evaluating the safety challenges and development targets of the train traffic control work.

The objective of this study was twofold; first, to understand the cognitive demands of the train traffic controller's task during railroad construction work, and second, to evaluate the prerequisites established by the organisations to perform the task safely.

2 METHOD

2.1 Analysis of train traffic controller's tasks

An empirical study and data collection on the task of train traffic controllers were conducted in the Eastern Finland Traffic Control Centre. At this Centre, seven traffic controllers worked at their own desks in a large room, each responsible for his or her assigned territory adjoining another controller's territory. In addition, one of the traffic controllers was in continuous contact with the main traffic control centre and informed on both the nationwide and adjoining regional control centres. There were differences in the technical equipment at the desks due to the varying ages of hardware or software. The centre controlled local commuter trains, long-distance passenger trains and freight trains. All together, six professional train traffic controllers of which three of them were experts (7-20 years experience in traffic control) and three were novices (1-3 years experience), participated in the field study. They worked at the three different desks, each of which placed different kinds of demands on controller's performance. The controlled territories and the techniques used at the selected desks differed: at one desk the controller's work focused on a station area without any centralised traffic control system; another desk controlled an area where there was undergoing an exceptionally large number of construction work and the third was responsible for some sections that were signaled, but without any centralised traffic control system (see Fig 1).

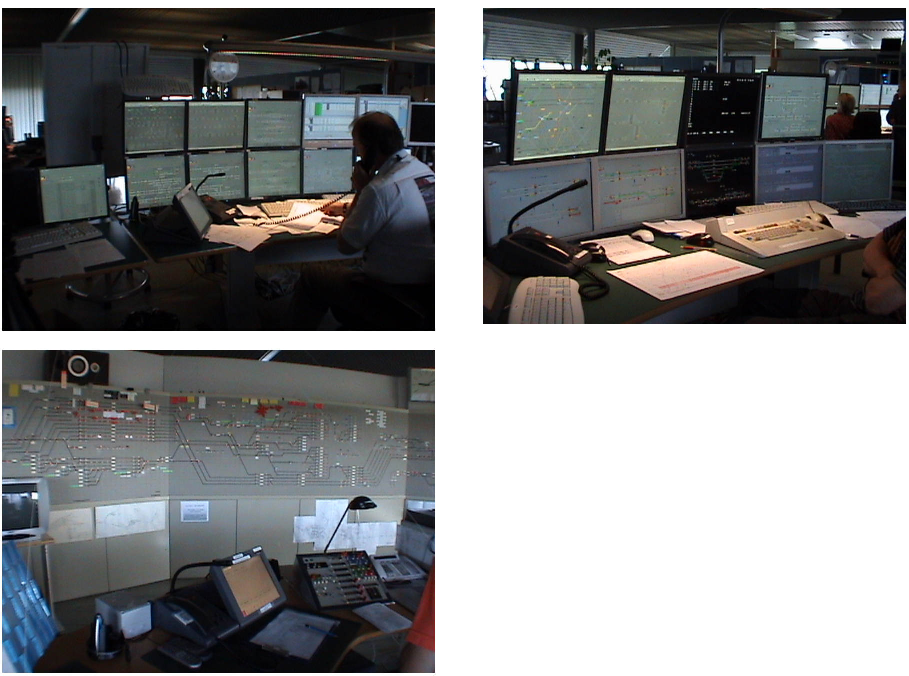


Fig.1. Three train traffic controller desks in the traffic control centre

The cognitive task analysis (CTA) was conducted to identify the cognitive requirements involved in train traffic controlling. The analysis focused on the processes of granting permission for railroad work and receiving information on the termination of the work.

In data collection, several methods were used. We began by video recording one controller as she/he was controlling rail traffic and granting permission for railway work in the early morning rush-hour period between 7:00 and 9:00 hours. Three controller desks were video recorded twice, with either a novice or an expert at work. Afterwards, the person was asked to think aloud while she/he was watching the performance on video. These think-aloud sessions were also video recorded. Secondly, the semi-structured interviews were conducted in order to elicit information on the critical elements of the work, the work demands and the organisational support functions. In addition, the researchers took photographs of the various tools and equipment at the desk, and traffic controllers were asked to explain the use and meaning of the tools in task performance. Also, a document analysis was conducted of the regulations and the work instructions related to the tasks of the train traffic controller.

In the data analysis, the main cognitive activity goal structure achieved was analysed using a hierarchical task analysis (HTA) [10]. HTA involves describing the activity under analysis in terms of a hierarchy of goals, sub-goals, operations and plans. The main result is the description of the parallel or sequential goals that operator have to achieve in order to complete the task.

2.2 Analysis of situation awareness elements

SA elements were determined based on the goal-oriented HTA. Because we identified a critical goal of ‘continuously monitor and control train traffic’ that ensures the safety of other activities, we concentrated on that goal in the analysis. We identified all the information the controller needed to make decisions in different situations in order to continuously monitor and control train traffic. During the semi-structured interviews, controllers were asked questions related to decision-making strategies in different situations i.e. required communication, roles of the actors, actions completed, tools used, information and knowledge needed and how they control complex situations. During the sessions, while the controller was watching his/her performance on video, he/she was encouraged to talk about the tools she/he used to accomplish the task. The SA elements were organised in terms of the controller’s task goals, rather than presenting it in technology-oriented information displayed on the different sensors or displays e.g. temperature or time. The aim of the SA analysis was to determine the prerequisites for maintaining situation awareness of the overall traffic situation.

2.3 Analysis of organisational support functions

In order to elicit additional information on the critical elements of the controller’s work, work demands and organisational support, a semi-structured interview was conducted with ten regulators, supervisors and planning engineers. The model of the organisational dimensions of safety culture [9] was used to evaluate the organisational support for safe work (Fig 2). The interviews covered themes concerning the roles of the organisations, safety management plans, norms, regulations, instructions, risk management, organisational learning practises, procedure management, resource management, competence and training management, workload issues, communication, technologies, change management and subcontractor management.

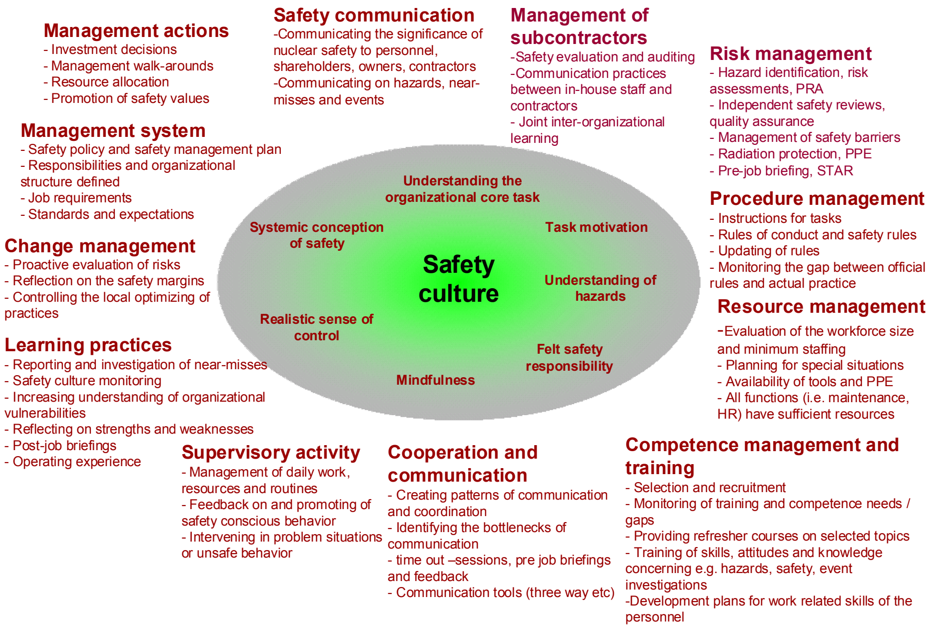


Fig.2. Model of the specific contents of the organisational functions of safety culture (Reiman and Oedewald 2009)

The analysis of the organisational functions had two aims. The first was to establish a basis for analysing the findings from the task mentioned above and the SA analysis. The findings from the previous phases of the study were put within a wider organisational context in order to be able to evaluate the risk they pose to the system safety. The safety effects of some task demands cannot be fully evaluated unless there is knowledge on the prerequisites required to fulfil the demand on the long run. Thus, the challenges controllers expressed and observed in terms of completing the task were compared to each of the organisational functions. This was done to identify which organisational functions contribute to the perceived or observed challenges of the controllers' work and to determine how this affects their work. The second aim was to identify safety challenges other than those identified in the task analysis.

3 RESULTS

The main goal in the controller's task is to control train traffic safety and efficiently. Figure 3 shows the train traffic controller's task when granting permission for railway work. In order to accomplish this goal, the controller has to monitor and control train traffic continuously. No sub-goals were studied because our focus was to analyse the goal decomposition in terms of railroad work. The controller starts to carry out the subordinate goal 'Grant permission for railway work when a safety responsible for a specific railway work calls and requests permission to start working. On these occasions, the controller's attention is momentary switched from monitoring and controlling train traffic to the process that includes six sub-goals (1.2.1. – 1.2.6.) in order to grant permission.

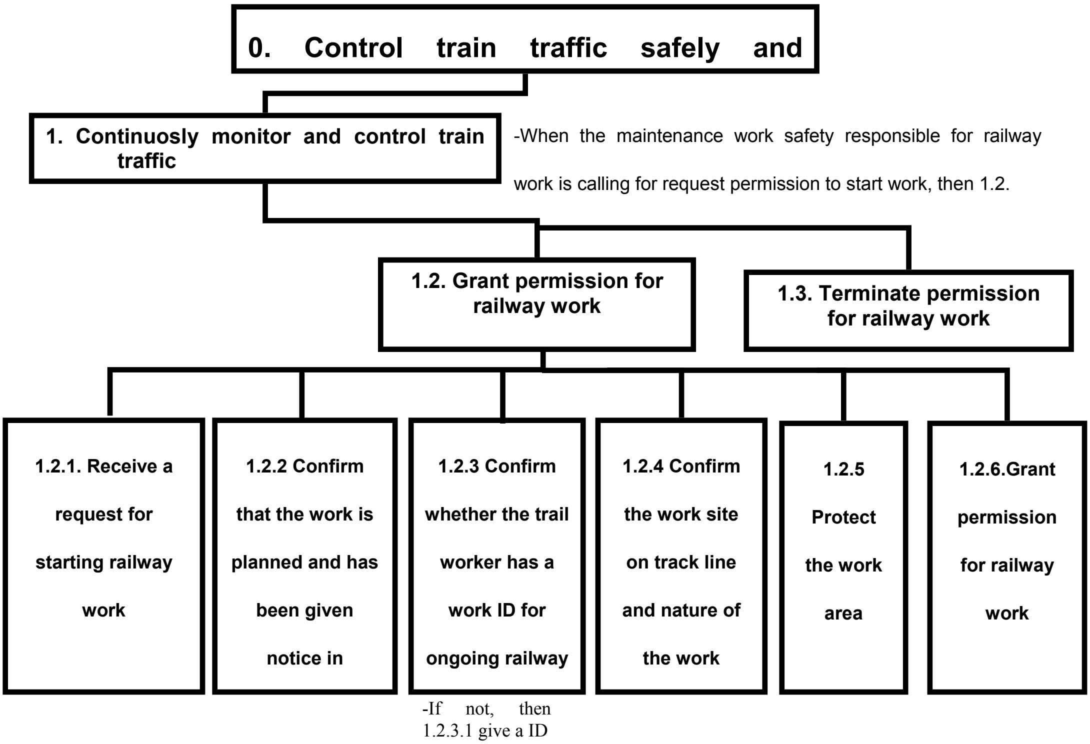
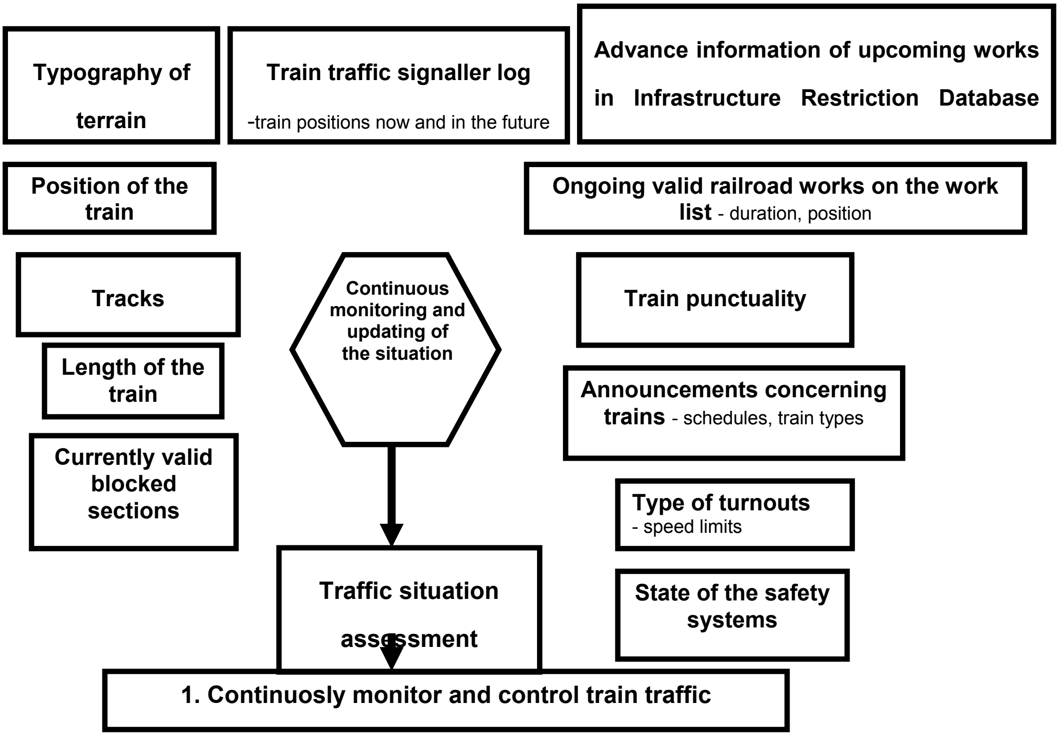


Fig.3. HTA of granting permission for railway work

However, when granting permission, the controller has to maintain an overall SA for monitoring and controlling train traffic. Twelve critical elements of SA were identified (Fig. 4). In practice, there was a continuous demand to monitor and anticipate track usage and upcoming events. Unanticipated events required dynamic re-planning, decision making and maintaining SA under time pressure. There were several demanding elements in the controller's tasks: continuous anticipation of the future situations, time pressure in decision making based on uncertain information, heavy working memory load, heavy communication and coordination demands concerning sometimes involving more than ten construction work teams, unexpected changes in track usage, various disturbances, difficulties to reach all the recently changed regulations and work instructions in dynamic situations. The controllers have developed their own strategies to face multiple demands especially during rush-hours (Table 1).

Fig.4. Elements of the train traffic controller’s SA



Controllers are actively monitoring various information sources. Whenever possible, they also monitor information beyond their current operations in order to anticipate upcoming events and activities.
Controllers provide one another with information to support such anticipation. They also consult with one another and with the controller’s supervisor when they anticipate disturbances in traffic or other events in the near future. A controller needs to consider various SA elements e.g. to successfully determine the order of the trains in a dynamic situation.
Controllers listen to the communication and calls of other controllers, whenever it is possible, to be able to anticipate the traffic situations in their own territory.
In rush-hours or demanding situations shift changes are postponed until the traffic is under control and safety is ensured.
The information received from multiple sources is verified, time permitting.
Controllers try to share their traffic situation awareness in advance with others, for example by calling the drivers of the long-distance passenger trains if traffic in running behind schedule.

Table.1. Sample of work practises of train traffic controllers to maintain SA

Controllers are actively monitoring various information sources. Whenever possible, they also monitor information beyond their current operations in order to anticipate upcoming events and activities.

Controllers provide one another with information to support such anticipation. They also consult with one another and with the controller's supervisor when they anticipate disturbances in traffic or other events in the near future. A controller needs to consider various SA elements e.g. to successfully determine the order of the trains in a dynamic situation.

Controllers listen to the communication and calls of other controllers, whenever it is possible, to be able to anticipate the traffic situations in their own territory.

In rush-hours or demanding situations shift changes are postponed until the traffic is under control and safety is ensured.

The information received from multiple sources is verified, time permitting.

Controllers try to share their traffic situation awareness in advance with others, for example by calling the drivers of the long-distance passenger trains if traffic in running behind schedule.

In parallel with the extensive railroad work projects, considerable changes in the organisations have also taken place. The railway signalling and safety systems as well as the information technology the controllers use in their daily work have changed. Furthermore, the organisational structure has changed. In 1995 the department in charge of planning, construction, maintenance and traffic control on railways was separated from the state-owned railway business: the Finnish Rail Administration (RHK) was born. In 2006 the Finnish Rail Agency (RVI) was established by separating the safety departments from the Finnish Rail Administration. During 2006-2009 the new agency served as the top railway safety authority, setting safety regulations for traffic operation and railway work, among others. At the beginning of 2010 the Rail Agency was reorganised into the Finnish Transport Safety Agency (TraFi) and the Rail Administration into the Finnish Transport Agency. The department reshaped from the former Rail Agency in TraFi establishes regulations for traffic operations, railway work and communications. The Rail Department (the former Rail Administration) in the Finnish Transport Agency provides working instructions to specify the regulations dealing with traffic control, traffic operation, railway work and communications. VR Ltd is the leading freight and passenger carrier in Finland and it provides the traffic control activities for the Rail Department. A large amount of extensive construction projects and rapid changes in the railway organisations and their mutual roles and responsibilities influence the controllers' tasks. This has been reflected e.g. in the punctuality of train traffic and incident statistics.

Due to the high task demands and the changes in the organisations, various development targets were identified from the organisational functions. For example subcontractor management and the practises of issuing work instructions should be developed to better support the traffic controllers' work. On the other hand, organisations had initiated several developmentals and programs in order to offer better support for work. In the management of railroad work contractors, new safety training and requirements were introduced. Systematic risk assessment and management were trained and implemented in to the railroad work processes. Co-operative coordination and information sharing forums were developed for better work management between the traffic controllers and contractors. These were also identified with the help of a systematic organisational analysis framework.

4 CONCLUSIONS

In this study, the cognitive demands of the train traffic controller's task and the organisational support functions that ensure that their tasks are safely performed during railroad construction work were analysed. Train traffic controlling during railroad construction work is a complex, cognitively demanding task that requires well-designed technical and organisational support functions to be accomplished safely. The complex and frequently, performed task of granting permissions and coordinating railroad work has to be accomplished without neglecting the task of continuously monitor and control train traffic. However, two parallel task goals require controllers to switch and divide their attention between the tasks and continuously update their situation awareness in order to manage both tasks during rush-hour periods.

In recent years, a new approach and concept known as resilience has emerged in safety management. Resilience focuses on the abilities of an organisation and people to cope with complexity and to recover from unexpected developments [11, 12]. Hollnagel [13] has argued that human performance must be variable as well, because of the complexity of socio-technical systems. The performance variability arises from the need to adapt to complexity and demands of the system. In train traffic controlling, workers have developed informal work practices that emerged in response to the task demands. These informal strategies enable controllers to achieve the task goals and to maintain safety. Recently, Roth et. al. [14] have also found that railroad workers and train traffic control dispatchers have developed a variety of informal work strategies in order to maintain system safety and to increase the resilience of work. According to Roth et. al. it is important to take into account the informal work practices in designing new technologies, because these are critical for maintaining system resilience. This doesn't mean, however, that the activities of these social-technical systems should not be managed systematically. It is important to understand how different organisational support functions should be developed in order to ensure that the human variability is anticipated and managed.

5 ACKNOWLEDGMENTS

This study was carried out in the Traffic Safety 2025 program conducted by VTT and funded by VTT and eight other parties including e.g. railway and road traffic authorities and companies. We would like to thank the train traffic controllers in the Eastern Finland Traffic Control Centre as well as all the interviewees for their cooperative participation in this study. Finally, we are grateful to the members of the railway experts' team who gave us valuable advice during the planning and the execution of the study.

6 REFERENCES

[1] Vicente, K.J., Mumaw, R.J., and Roth, E.M.: 'Operator monitoring in a complex dynamic work environment: a qualitative cognitive model based on field observations', Theor. Issues in Ergon. Sci., 2004, 5, (5), pp. 359-384

[2] Crandall, B., Klein, G., and Hoffman, R.R.: 'Working minds: a practitioner's guide to cognitive task analysis', (The MIT Press, 2006, 1st edn.)

[3] Schraagen, J.M., Chipman, S. F., and Shalin, V.L. 'Cognitive task analysis', (LEA, 2000, 1st edn.)

[4] Wickens, C.D., Lee, J.D., Liu J.D., and Gordon Becker, S.E. 'An introduction to human factors engineering', (Prentice Hall, 1997, 2nd edn. 2004)

[5] Endsley, M.R., Bolte, B., and Jones, D. G., 'Designing for situation awareness: an approach to user-centered design' (Taylor & Francis, 2003, 1st edn.)

[6] Endsley, M.R.: 'Towards a theory of situation awareness in dynamic systems', Human Factors, 37, (1), pp. 32-64

[7] Roth, E.M., Multer, J., and Rashlear, T.: 'Shared situation awareness as a contributor to high reliability performance in railroad operations', Organization Studies, 2006, 27, (7), pp. 967-987

[8] Rasmussen, J.: 'Risk management in a dynamic society: a modeling problem', Safety Science, 1997, 27, (2/3), pp. 183-213

[9] Reiman, T., and Oedewald, P.: 'Evaluating safety-critical organizations – emphasis on the nuclear industry', (SSM research report, Swedish nuclear safety regulator, 2009, 12)

[10] Shepherd, A.: 'Hierarchical task analysis' (Taylor & Francis 2001, 1st edn.)

[11] Hollnagel, E., Woods, D.D., and Levenson, N.: 'Resilience engineering', (Ashgate 2006, 1st edn.)

[12] Hollnagel, E.: 'The four cornerstones of resilience engineering', in Nemeth, C.P., Hollnagel, E., and Dekker, S. (Eds.): ' Resilience engineering perspectives, Volume 2: preparation and restoration' (Ashgate, 2009, 1st edn.), pp. 117-133

[13] Hollnagel, E.: 'Barriers and accident prevention', (Ashgate 2004, 1st edn.)

[14] Roth, E.M., Multer, J., and Scott R.: 'Understaning and contributing to resilient work systems', in Nemeth, C.P., Hollnagel, E., and Dekker, S. (Eds.): ' Resilience engineering perspectives, Volume 2: preparation and restoration' (Ashgate, 2009, 1st edn.), pp. 215-234