Railway safety and the train driver information environment

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Abstract

The TRAIN project investigates traffic safety related risks, focusing in particular on the train driver work situation, use of information but also on the supporting safety organisation. It is an on-going project funded and managed by Swedish National Rail Administration and carried out by independent researchers. The project provides a multi-disciplinary investigation using task and ergonomic analyses, usability evaluation of the ATC system and analyses of stress, mental workload and work hours. Several methods are being used such as interviews, questionnaires, diaries, activity monitoring and videotapes. Results from parts of the project show that there is a lack of human factors data in accident reports and that drivers report severe problems concerning sleepiness on early morning shifts, problems with maintenance on vehicles as well as problems in understanding ATC functions. The problem areas identified show that there is a need for scientific studies of human factors and railway safety as well as safety management programs including professional human factors competence in the railway industries.
1 Introduction

The investigation of railway safety and human factors in a system perspective is the focus of the TRAIN project, a research project funded and managed by the Swedish National Rail Administration (Banverket) and carried out by independent researchers. The purpose of the project is to identify traffic safety related risks and to suggest safety enhancing measures in the train driver system, focusing in particular on the train drivers’ work situation, use of information as well as on the supporting safety organisation. Issues concerning the drivers’ use of information, cooperation, organisation, stress, work hours and work environment are investigated for driving conditions such as commuter and high speed trains.

The project is the result of recommendations from several accident and incident investigations which identified work situation, use of information and lack of training as important contributory causes, thus concluding that human factors issues and railway safety should be further investigated (e.g. Jacobsson, [1], Statens haverikommission [17]). It is assumed that stress and the highly irregular work hours may have a negative impact on driver performance and could be associated with human errors, for example signals passed at danger. Over the years there has been much concern as to the effects of the ATP system on driver behaviour and performance. “ATC dependence” and “ATC-behaviour” has been the concept used when referring to a wide variety of unexpected and unwanted driver actions. However, there has been no comprehensive research on these issues, apart from a few pilot studies (Svensson [2], Ohlsson [3] and Harms, et.al. [4]).

When investigating safety it is important to address the multiple, interacting system and factors which in combination contribute to safety and efficient train operation. For the purpose of the TRAIN project the concept used was the train driver system defined as the function, technology, driver and organisation involved in operating a single train.

2 Methodology

The TRAIN project includes, firstly, a review of the literature and an explorative analysis of accidents and incident reports, secondly, an analysis of the train driver system using different theoretical approaches as presented below, and thirdly recommendations for safety improvements as well as suggestions for the future design of the train driver system.

At present, the review of the literature and the analysis of accident reports have been completed, as presented in the list of reference. Parts of the analysis concerning work situation and work hours have also been completed. Many of the other activities are still on-going projects.
2.1 The train driver system

The investigation of the train driver system includes an identification of the organisational safety support functions, such as incident investigation systems, vehicle maintenance and train traffic control, but also the dynamic train driving task. The study includes a description of the regulatory authorities, the infrastructure manager and the train operator perspective. It is carried out using interviews and studies of documentation. A structural model of factors influencing the train driver system is being developed in this part of the project. This is an on-going activity.

2.2 Train drivers work situation and work hours

A detailed analysis of work situation, stress, mental work load and work hours in relation to commuter and high-speed trains as well as different work schedules was also carried out. Data was collected using a questionnaire. In addition, an in-depth longitudinal study of sleep, alertness and performance was carried out for forty-six drivers using diaries as well as activity monitoring.

2.3 Task and cognitive ergonomics analysis

A detailed analysis of the commuter train as well as the high-speed train driving task was performed using a task and barrier analysis methodology (Skjerve et.al. [5]). The function of a barrier is either to prevent an action from taking place or to protect the system and the people from its consequences. A classification framework for different barriers was also developed (Hollnagel, [6]).

This part also includes a usability evaluation of the Swedish ATC system focusing on driver behaviour while interacting with ATC (Olsson et.al. [7]).

The methodologies used were interviews, observations and an additional questionnaire for the ATC usability evaluation.

2.4 Identification of risks and problem areas in the train driver system

The basic idea behind the TRAIN project is to combine different theoretical approaches addressing the organisational and workplace levels and to integrate this information in order to identify risks in the train driver system.

2.5 Subjects

Drivers at the train operation company SJ (Swedish State Railways) based in Stockholm participated in all parts of the project. The entire train driver population consisted of approximately 400 drivers.
3 Results

3.1 Review of the literature

From the review of the literature it could be concluded that relatively few studies had been carried out concerning working conditions, work hours and sleepiness. Many of these studies are twenty years old. As to the drivers’ use of information and interaction with the ATC system only a few pilot studies have been carried out. Recently, the train drivers’ work hours and work situation have been studied in USA and Australia (e.g. Dawson, et.al. [8]). Also, as a result of experimental research a man-machine interface display panel for the European Train Control System (ETCS) has been suggested (ERRI, [9]).

3.2 Analysis of accident reports

Eighty accident reports from the period 1980-1997 were studied in the TRAIN project. These reports varied extensively as to the amount of information included and, in general, information concerning human factors was missing. It could be concluded that it is important that the railways develop a structured method for analysis of railway accidents, including comprehensive human factors information. Also, a multidisciplinary team including human factors specialists should perform the investigation. In future accident reports such information should be included as previous involvement in accidents, training history, reliability of the technical system, rules, communication and orders and possible barriers that should be strengthened or implemented. It could be concluded that in most accidents there had been a deviation from the normal operating circumstances preceeding the accident (Jansson, et. al. [10], Hollnagel, et.al. [11]) In about one third of the accidents stress and fatigue seem to have been contributory factors (Kecklund, et.al. [12])

Findings from the review of the literature and the analysis of accident reports related to the specific research areas in TRAIN are presented below.

3.3 Organisation, training and safety awareness

The results concerning the overall train driver system indicated extensive problems with maintenance on vehicles, on commuter trains especially but also on high-speed trains. 80% of the commuter train drivers reported that the maintenance on the commuter trains was very poor and many stated that there were problems with safety awareness among managers and contract staff. The drivers wanted more training on ATC and safety regulations. Also, a great majority of the drivers (80-90%) report that the incident and near-miss reporting systems function poorly. In addition a majority of the drivers (65-70%) think that the safety rules are difficult to understand (Lindberg [3]).
3.4 Train drivers work situation, workload and work hours

3.4.1 Work situation

The different sources of stress and work load in the train drivers task and the effects on safety and performance parameters as identified in previous studies were summarized in Kecklund et. al.[12]. Previous Swedish studies from the seventies and eighties (Åkerstedt, et.al. [14]) identified irregular work hours, in particular night and early morning work as well as physical factors such as noise, vibrations, problems with maintenance of vehicles and poor cab environment as being critical work environment problems. New load factors during the nineties were expected to be organisational changes such as downsizing and possibly increased mental workload. The effects of the large structural changes within the railway sector, due to the deregulation of the railway operation market, could also be expected to increase the train driver work load and effect work satisfaction and worker motivation.

3.4.2 Stress and work load

The sources of stress and work load in the present work situation were investigated in a questionnaire study concerning the train drivers' work situation, sleep, health and mental workload. The return rate in the study was 72%. The results show that the drivers experience more stress, worse sleep quality, more sleepiness and lower job satisfaction. They also report more social problems (with family) as compared to several other shift work groups in industry. The results indicate that the risk of the drivers developing chronic stress and fatigue is high (Ingre, et.al. [15]).

3.4.3 Work hours

The drivers work hours were highly irregular, involved a high proportion of early morning and night shifts (42%), very often with short rest periods between the shifts (in some cases even as short as 4 or 5 hours).

Stress, sleepiness, fatigue and sleep disturbances were related to a higher frequency of self-reported, work-related errors. Sleepiness and lack of job motivation were the most important factors explaining serious mistakes at work. 19% of the drivers showed symptoms of clinical sleep disorders (insomnia), a high percentage compared to day-time workers but also to other shift-work groups. Insomnia was also associated with pronounced sleepiness in early morning and night shifts. The group involving drivers with severe sleep problems had also been involved in incidents and accidents more often (Ingre, et.al. [15]).

3.4.4 Errors and problems in the work situation

The drivers rated the risk of running over a person as the most troublesome in the work situation. A great majority of the drivers had been involved in an accident during the last three years. Approximately 25% of the drivers had had accidents when running over people. The drivers also reported that own errors, such as minor errors resulting in the automatic activation (braking) of the ATC were
quite frequent, as were the technical balise errors. These errors occurred at least once a week for each driver. The drivers also got an emergency ATC brake more than once a year. In general severe errors were seldom reported (Ingre, et.al. [15]).

3.5 Usability evaluation of the ATC system

3.5.1 The ATC system
The first version of the Swedish ATC system was implemented in 1979-1980 and more advanced functions were added in 1993. When using this system the driver remains the operator with all actions being supervised by the ATC system. In the Swedish system the driver is supplied with speed information at his desk. The system is supplied with intermittent information transfer through balises located at trackside signal locations where data from the signaling equipment is collected. Other important functions of the system are to memorize the train description data entered by the driver and to permanently compute and supervise the speed of the train in real time. Actions initiated by the system are to warn the train driver of overspeed and to activate emergency braking in an abnormal situation.

3.5.2 Driver evaluation of ATC
The questionnaire study of the use of ATC carried out when the ATC system had been in operation for ten years revealed that the system had been an important safety tool, but also that there had been reliability and availability problems as well as inconsistencies between trackside signalling information and in-cab ATC information. Furthermore it was concluded that the drivers had adapted their driving style to the ATC functions (Ohlsson, et.al. [3]). However, the questions of how the driver adapts his or her behaviour to the ATC system as well as the effects on driving performance still remain to be answered.

The analysis of the results from the usability evaluation is on-going. Preliminary results from the usability evaluation of the ATC system indicate problems with driver knowledge of ATC functions, in particular in relation to the signalling system (Olsson, et.al. [7]). Also drivers report that ATC is very important for the driving task and put great trust in the system. However, 40-60% of the drivers also want more training concerning the ATC system, basic as well as recurring. (Lindberg, et.al. [13]).

3.6 Task and cognitive ergonomics analysis
A task analysis procedure based on operational sequence diagrams was used as a basis for a detailed task and barrier analysis as well as for an analysis investigating the relation between the train drivers' goal formulation process and the development of the train drivers' mental model of the driving task.
4 Conclusions

4.1 Preliminary results from the TRAIN project shows that;
- Drivers report severe problems concerning sleepiness at the job in particular in relation to early morning shifts, with a higher frequency of sleep problems as compared to other shift-work groups
- There is a relationship between drivers’ self-reports of sleepiness, stress and work-related errors
- There is a relationship drivers’ reports of sleepiness and lack of job motivation and self-reports of serious errors at work
- Drivers report problems with maintenance on vehicles, near-miss reporting systems, safety rule systems and safety awareness
- There are problems with drivers understanding of some ATC functions
- There is a lack of human factors data in accident investigation reports and there is a need to apply a railway specific, structured methodology for accident investigations including different competencies
- There is a great need for new studies of human factors and railway safety, in particular considering new work practices on a deregulated market.

4.2 Implication for railway safety

At present, only part of the data concerning the train drivers’ present work situation has been analysed. The results indicate that work hours and stress are very important load factors in the work situation and that those factors are likely to contribute to degraded work performance for the train driver and thus for the entire train driver system.

Also, several accident and incident investigations have indicated problems with the drivers understanding of the ATC functions especially in situations where those functions are degraded (e.g. Jacobsson [1]). This is supported by preliminary results from this project (Olsson [7]). This suggests that temporary degradations in ATC functioning due to for example maintenance activities and temporary system failures are particularly vulnerable states in train operation.

4.2.1 Dangerous conditions

Lack of information and degraded automatic supervision in combination with unfavourable work schedules, stress and decreased motivation for work might represent a dangerous condition for the train driver system. This can be
illustrated by a quote from a driver answering the ATC usability questionnaire: “I would probably not be able to manage the high driving tempo today without the support of ATC” (Olsson, et.al [7]).

In summary, psychosocial and work environment factors are very important for high performance of the train driver system. The optimal design of these factors will constitute a prerequisite to enabling the driver to use the information necessary for the work task correctly and efficiently, and thus have a highly safe and high performing train driver system.

Also, the changing role of the train driver where new safety and control systems enables a higher level of automation makes it particularly important to create a active driver role and good psychosocial work conditions to ensure a high driver alertness.

During the last two years several serious train accidents have occurred all over Europe; in Germany, Switzerland, Norway and Great Britain. In most of these cases errors in the train driver system or in maintenance seem to have been an important contributory cause. However, there are still very little human factors competence and methods used within the railway section, in particular in comparison with the research and competence on human factors and safety used in aviation, road transport and process industries.

4.3 Future work

4.3.1 Research

There is a need for a coordinated international effort in the investigation of human factors and railways, in particular when considering the large structural changes within the railway sector. This effort should among other things address the implication of workload, irregular work hours, use of automation and the drivers role, drivers understanding of degraded system functions as well as the implications on various system performance indicators such as for example signals passed at danger.

4.3.2 Railway industry

As for the partners in the railway industry, effort should be directed to develop proactive safety measures such as countermeasures to manage high workload situations and to improve work schedules with the purpose of optimizing drivers performance. In addition, work processes should be developed which consider human factors issues, in particular the drivers’ psychosocial work environment, when designing new vehicles and equipment. Also, safety management programs including human factors programs should be developed as has been done in the aviation and process industries.
References


