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The TRAIN –project:

Railway safety and the train driver information environment and work situation

- A summary of the main results

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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 by use of a man-technology-organisation (MTO) perspective. Activities performed are task analysis, evaluation of the drivers' use of information and interaction with the ATP system as well as analyses of stress, mental workload and work hours. Several methods are being used such as interviews, questionnaires, diaries, activity monitoring and videotapes. This paper gives an overview of the project as well as a short summary of the main results. Detailed results are presented in separate reports as stated in the reference list.

Some of the main results are that the drivers report severe problems concerning sleepiness on early morning shifts, problems with maintenance on vehicles, lack of information supporting the planning task as well as problems in understanding ATP functions. Two groups of drivers having a feedback related as opposed to a feed-forward driving style could be identified. In conclusion there is a great need to perform more scientific studies of human factors and railway safety as well as

to implement safety management programs including professional human factors competence in the railway industries.

Introduction

The investigation of railway safety and human factors by use of 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 and 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. From the literature review in the TRAIN project it could be concluded that relatively few recent studies had been carried out concerning working conditions, work hours and sleepiness. Recently, the train drivers' work hours and work situation have been studied in USA and Australia (e.g. Dawson, et.al., 1998). Over the years there has been much concern as to the effects of the ATP system on driver behaviour and performance. "ATP dependence" and "ATP-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 1977, Ohlsson, 1990 and Harms, et.al., 1996). Also, as a result of experimental research, a man-machine interface display panel for the European Train Control System (ETCS) has been suggested (ERRI, 1996).

When investigating safety it is important to address the multiple, interacting systems and those factors which in combination contribute to safety and efficient train operation and therefore the man-technology-organisation perspective was chosen. 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.

Methodology

The TRAIN project includes, firstly, a review of the literature and an explorative analysis of accidents and incident reports (Hollnagel et.al., 1999a, 1999b, Jansson, et. al., 1999, Kecklund, et.al., 1999), secondly, an analysis of the train driver system using different theoretical approaches as presented below, and thirdly, recommendations for safety improvements.

The train driver system

The study includes a description of the regulatory authorities, the infrastructure manager and the train operator perspectives assumed to be important for the safety of the train driver system. It was carried out using interviews and studies of documentation. A structural model of factors assumed to influence safety in the train driver system has been developed in this part of the project (Lindberg, et. al., 2000).

Train drivers work situation and work hours

A detailed analysis of work situation, stress, mental workload 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 (Ingre, et.al., 2000) as well as in an in-depth longitudinal study of sleep, alertness and performance using diaries and actigraphy (Söderström, et.al., 2001).

Task and cognitive ergonomics analysis

The train drivers' task was analysed using a control theory framework. The methodologies used were interviews, observations and video recordings.

A questionnaire evaluation of the drivers' use of information and interaction with the ATP system was also performed (Olsson, et.al., 2001).

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 and problems in the train driver system.

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.

Results

Results from the 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 preceding the accident (Jansson, et. al., 1999, Hollnagel, et.al. 1999a, 1999b) In about one third of the accidents stress and fatigue seem to have been contributory factors (Kecklund, et.al., 1999)

Results concerning organisation, training and safety awareness

When considering issues related to the overall train driver system the drivers reported problems with maintenance on vehicles, especially on commuter trains 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%) reported that the incident and near-miss reporting systems function poorly. In addition a majority of the drivers (65-70%) thought that the safety rules were difficult to understand (Lindberg, et.al., 2000).

Results concerning the train drivers' work situation, stress, workload and work hours

Stress and work load

The sources of stress and workload 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 and also more social problems (with family) than other comparable groups. The results indicate that the risk of the drivers developing chronic stress and fatigue is high (Ingre, et.al., 2000).

Work hours

The drivers' work hours were highly irregular, involved a high proportion of early morning (starting before 06.00) and night shifts (ending after 04.00), approximately 42%, very often with short rest periods between the shifts, in some cases even as short as 4 or 5 hours. Early morning shifts constituted 28% of the total number of shifts. In the diary study and activity study the results showed that the mean sleep time for the drivers before early morning shift was 4,5 hours (Söderström, et.al., 2000).

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 daytime workers but also to other shift-work groups. Insomnia was associated with pronounced sleepiness in early morning and night shifts. The group of drivers showing symptoms of insomnia had also been involved in incidents and accidents more often (Ingre, et.al., 2000).

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 some 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. In the diary study the drivers reported that balise errors occurred at approximately every fourth work shift (Söderström, et.al., 2000). The drivers also got an emergency ATP brake more than once a year. In general, severe errors were seldom reported (Ingre, et.al., 2000).

Concerning SPADs 230 out of the 265 drivers reported that they had never had a SPAD and 20% reported that this had occurred at least once during the previous year.

Results concerning the train drivers' use of information and interaction with the ATP system

The driving task and information environment

The train-driving task is a dynamic control and decision-making task. To complete his driving task the driver has to use and integrate information from several sources; information from line side signals and signs, ATP information, route book and timetables, rule book and different kinds of safety messages informing the driver in real time. It is therefore important to investigate the drivers' use of information from the different sources as well as the interfaces transmitting the information to the driver and to analyse the cognitive demands put on the driver. Analyses of the driving task were performed by use of a control theory framework (Jansson, et.al., 2000).

In general it is important to provide sufficient information to the driver about the system state to support the control task and to give information about the dynamic system changes to enable the driver to develop a mental model of the task and technical systems. The results indicate that not enough information is provided to the driver by use of the existing modes of presentation. More information should be provided, and the information presented as well as the format of presentation should support the drivers' natural understanding of the driving task preferably by use of a graphical interface inside the cab (Jansson, et.al., 2000).

The search for information in different sources, e.g. different kinds of documents, in cab as well as line side information, requires the driver to divide his attention and might take attention from the primary task of driving the train. These attention conflicts should be avoided in particular in platform situations where the driver must be fully concentrated on passengers boarding and leaving the train. Information that is now presented in several documents and other systems and should be integrated by the drivers should be presented to the driver in an integrated manner. Dynamic information should be presented to the driver.

The system presents very little information to the driver concerning the task of planning ahead. This information is available at the train traffic control centre but not to the driver. The potential of sharing information between drivers and train traffic controllers should be further investigated (Olsson, et.al., 2000). The drivers use previous experience and expectations to compensate for the lack of information for planning the driving task ahead.

As to drivers' interaction with the ATP system results from the task analysis indicate that some drivers do not even try to understand why ATP stops the train at certain signals or intervenes in other ways. They seem to have got used to the fact that this information is not available and that they will not be able to understand.

The Swedish ATP system

The first version of the Swedish ATP 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 ATP 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 signalling equipment is collected. Other important functions of the system are to memorize the train description data entered by the driver and to continuously compute and supervise the speed of the train in real time. Actions initiated by the system are to warn the train driver of over speed and to activate emergency braking in an abnormal situation.

Driver evaluation of information and the ATP system

The return rate in the questionnaire study concerning the drivers' use of information and interaction with the ATP system was 60%.

All drivers report that ATP is a very important support system for the driving task and most put great trust in the system.

However, many drivers, in some cases 50%, provided the wrong answer to questions addressing the declarative aspects of their knowledge of the ATP system and the interaction with other parts of the signalling system. The drivers were also asked to describe a situation where they had identified discrepancies between the ATP information and the rail side signals. Many of the situations described were those where ATP functioned according to the rulebook, but several drivers seemed not to know this (Olsson, et.al., 2001). 40-60% of the drivers stated that they want more training concerning the ATP system, basic as well as recurring (Lindberg, et.al., 2000).

The drivers reported making several errors while fetching data for the ATP and entering data into the system. In particular, it was easy to forget to make new data entries when this had to be performed while driving on the line (Olsson, et.al., 2001).

A goal conflict was found between a safety speed restriction function and the production goal of being able to accelerate fast after a stop while driving a commuter train. A group of drivers reported that they often tried to go around this speed restriction function to achieve the production goal.

Differences in driving style

Two different driving styles could be identified, drivers having a more feed-back related driving style, acting on the ATP indications as opposed to drivers having a feed-forward driving style trying to act ahead of indications (Olsson, et.al., 2001). These results are supported by data from the task analysis (Jansson, et.al., 2000). The present man-machine interface supports a feedback related driving style. This driving style was consistent across drivers for while driving both commuter and high-speed trains. Also, the drivers who were less experienced more often adopted the feedback related driving style.

The results provide no conclusive evidence concerning which driving style is the most effective from a safety point of view. However, the feedback related driving style cannot be adopted when the ATP system malfunctions. The driver then has to adopt another driving style while having to act without support of ATP. This might be difficult since the feedback related driving style is a well-practiced behaviour. A situation where ATP is not working presents a vulnerable condition for drivers with this driving style. From a production point of view the feedback related driving style might be more effective because it will optimise the use of the entire train traffic system. The results indicate that the drivers adopting a more feed-forward driving style report being more insecure of the ATP system. Thus a high technical reliability in all parts of the safety and control system is necessary if the feedback related driving style should be most efficient from a safety and production point of view.

In general, few differences were identified between the commuter and high-speed driving task.

In conclusion, when analysing Swedish accident statistics after the introduction of the ATP system the number of passenger accidental fatalities has been greatly reduced. Part of this reduction is most probably related to the introduction of the ATP, an important safety and information system for the driver in particular in situations with sleepiness and attentional problems. ATP was assessed as the most important source of information for both commuter and high-speed trains. However, the problems identified in this study concerning the man-machine interface and lack of planning information as well as the drivers´ problems concerning the understanding of the system should be recognized and improvements should be made.

Recommendations concerning safety-enhancing measures

The recommendations concerning safety enhancing measures concerning organisational issues includes improvement of the incident and near-miss reporting system, the rule book as well as to improve the maintenance of vehicles. Banverket is presently improving the rulebook. A good safety culture is crucial for the implementation of an efficient incident and near-miss reporting system. Also, to ensure relevant and adequate training, basic as well as recurrent is important.

The recommendations concerning the man-machine interface and driver cab presentation includes making more information available to the driver, in particular information which supports the drivers natural way of managing the task and use a format which supports the natural performance of the task such as graphical display format. Information, e.g. rulebook and other driving documents should be presented in an integrated manner.

Some of the important areas for improvement of the ATP system are to create a new man-machine interface and to increase drivers' knowledge of the relationship between ATP and other parts of the signalling system as well as the rulebook. Also, the safety implications of different driving styles must be further investigated.

The recommendation concerning work hours, mental workload and stress lies in the areas of reduction of work hours for the most strenuous shift schedules, ensuring adequate rests hours between shifts, avoiding long work hours on early morning shift, training of drivers in shift management strategies, rehabilitation program for drivers with severe sleep disturbances, measures to increase work satisfaction and also to create a more stimulation and interesting work task as well as improving the physical work environment.

Conclusions

Dangerous conditions

The results imply that several factors are important for the safety and efficiency of the train driver system, separately as well as interactively.

Some of the problems which might result in a dangerous situation are; lack of information and degraded automatic supervision in combination with unfavourable work schedules, stress and low motivation for work might represent a dangerous condition for the train driver system. This is particularly dangerous for drivers with a feedback related driving style.

These interacting factors can be illustrated by a quote from a driver answering the ATP questionnaire: "I would probably not be able to manage the high driving tempo today without the support of ATP" (Olsson, et.al, 2001).

There is also the lack of understanding of the ATP functions especially in situations where those functions are degraded. The feedback related driving style might be particularly vulnerable in this respect. This suggests that temporary degradations in ATP functioning, due to for example maintenance activities and temporary system failures, are particularly vulnerable states in train operation.

Important questions for the future concern how to design the train-driving task to improve understanding of the technical support systems and provide information to support the control and planning task, as well as to ensure an alert and well-motivated driver.

In summary, psychosocial and work environment factors as well as adequate content and format of the information as presented to the driver 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. Results from the TRAIN project indicates that if the driver is to stay within the system he should be given a qualified and stimulating work task and adequate support to complete this task.

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 as well as problems with technical reliability seems to have been an important contributory cause. However, there is still very little human factors competence and methods used within the railway sector, in particular in comparison with the research and competence on human factors and safety used in aviation, road transport and process industries.

Future work

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.

As for the partners in the railway industry, effort should be directed to develop proactive safety measures and safety management programs including good ergonomic design and countermeasures to manage high workload situations and to improve work schedules with the purpose of optimising drivers' performance.

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