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Train drivers' working conditions and their impact on safety, stress and sleepiness: a literature review, analyses of accidents and schedules

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Psychosocial medicine

is the collective term for the pan-scientific research into different living environments - how they are experienced and how they affect the human body, negatively or positively.

The human environment is filled with psychosocial risk situations. Many of these can cause physical problems, disorders or injuries. The purpose of psychosocial medical research is to study the relationship between such situations and human emotional reactions, behaviour, physiological reactions and physical or mental ill-health. The research is, therefore, interdisciplinary and involves experimental studies, both in the laboratory and out in the field, and epidemiological surveys.

In Stockholm, this research is conducted in a unique co-operation between

*** The IPM – the Institute of Psychosocial Medicine**
*** The Department of stress research at Karolinska Institute**, which is also
*** The WHO Psychosocial Cooperation Centre,** and
* **The Centre for Suicide Research and Prevention** at **Stockholm County Administration**.

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SUMMARY

The present paper reports the results of a literature review, an accident analysis, and an analysis of the work hours for three train driver groups. The report is part of a Swedish research project (TRAIN) initiated by the Swedish National Rail Administration (Banverket) in co-operation with the Swedish State Railways (SJ). These part of the project focuses on how the train drivers' work hours and work situation influence safety and performance, in particular in traffic intense areas, such as commuting.

Earlier studies identified work hours and the physical work environment as the major contributors to work load. With respect to work hours, night and early morning shifts caused a high level of fatigue and sleepiness, as well as disturbed sleep. Short rest periods between shifts were another cause to fatigue and sleep problems. However, it may be questioned whether the previous studies are relevant to the work situation of today due to technological changes, for example automatic train control (ATC) devices. Only a few studies have investigated commuter train drivers. In addition to the difficult work hours, the commuter drivers also report that vandalism, people present on the track (or close to the track), and unruly passengers cause problems in the work situation.

A few studies have examined accidents in relation to sleepiness/fatigue and work hours. It has been observed that fatigue related accidents mainly occur in connection with night shifts. The present report includes an analysis of 79 accidents and it was found that approximately 17% of the incidents might be related to fatigue or sleepiness. We also made an analysis of the rosters for the train drivers (n≈270) based in Stockholm. The analysis was made separately for the commuter group, the X-2000 group (high-speed train drivers) and the mixed group (both commuter and long-distance trains). The commuter group had more night shifts, whereas the X-2000 group involved more shifts with a short (9 hours or less) rest period prior and less breaks per shift. All groups were relatively often (>25% of the shifts) exposed to early (start time occurring before 06.00h) mornings shifts.

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INTRODUCTION AND PURPOSE

The work of the train driver is demanding and full of responsibility. The driver is in charge of both safety and punctuality, a job which requires a high level of concentration and alertness when it comes to signals, information, the tracks and his immediate environment. Since the introduction of ATC (automatic train control – an automatic safety system which monitors speeds and which takes over control of the train if the driver fails to observe a stop signal or a signal to reduce speed) the job today involves a greater degree of monitoring work, provided that there is no operational disruption.

The extremely irregular working hours constitute an added workload for the train driver, and this is exacerbated by the way the driver is not allowed to decide for himself when to take breaks.

The physical working environment can also give rise to workload; this includes, for instance, noise (or distressful noise levels), vibrations or an uncomfortable cab climate (too hot, too cold, draughty).

The train driver is also exposed to a demanding psychosocial working environment, which includes solitary work, limited opportunities for social contact with colleagues and a heavy responsibility for operating the train (in terms of both safety and adhering to the timetable). An important component of the psychosocial working environment is the ability to influence and control your own working situation. The train driver's job, i.e. to operate the train, is largely governed by timetables and technical conditions (e.g. type of train, track area), which restricts the driver's ability to decide for himself how the job is to be done.

There is a risk that all these factors (both psychological and physical demands plus working hours) will conspire to reduce safety and impair health. The purpose of this report is to:

1) summarise earlier research on the working conditions of train drivers,
2) report the results of accident report analyses (with an emphasis on working conditions), and
3) report the results of an analysis of the timetable for train drivers located at Hagalund station (in the Stockholm area).

This publication constitutes IPM's concluding report on phase 1 of the TRAIN project (TRAIN stands for "Traffic Safety and Information for Train Drivers"). The project is financed by Banverket (Swedish National Rail Administration) and run in association with SJ (Swedish State Railways). TRAIN consists of three subprojects, of which this one (subproject 3) considers train drivers' working hours and working conditions and their impact on performance and safety, particularly in densely trafficked areas.

The TRAIN project originated from the recommendations of the Board of Accident Investigation following the Älvsjö commuter train accident in 1994 (Board of Accident Investigation, 1994). One of the recommendations of the investigation was that a comprehensive study should be conducted of the safety aspects of the train drivers' working conditions in the Stockholm region, as well as an analysis of the impact of the ATC system on driver behaviour. The traffic operator SJ also wanted to receive clarification of the train driver's working conditions in terms of the following critical factors: high pace of traffic, punctuality demands, the risk of threats and violence at work, the scheduling and length of working hours and the occasionally repetitive nature of the work. To date, no comprehensive study of train drivers' information environment and working conditions has yet been made in Sweden.

The report will form the basis of a field study of the impact of working conditions on safety, with a focus on train drivers in Stockholm (Hagalund).

PREVIOUS RESEARCH – WORKING HOURS, STRESS, FATIGUE AND SAFETY

As there are relatively few published studies on train drivers' working conditions, we have included studies of other occupations that are of relevance to the project's line of questioning. In this section we will also be introducing certain basic concepts to explain why irregular working hours, stress and high mental workload increase the risk of accident and driver error.

Swedish studies on the work of train drivers: the effect of working hours

During the seventies, a number of Swedish studies were carried out concerning the working conditions of the train driver. These studies often addressed the problems related to the irregular working hours. Kolmodin-Hedman and Swensson (1975) carried out one of the first. One of the most salient results of this study was that the irregular working hours disrupted the drivers' sleep in connection with night and early morning shifts. A period of daytime sleep following a night shift lasted for about five hours, with the amount of nighttime sleep before an early morning shift being only insignificantly longer. The study also uncovered seasonal variations, with the amount of sleep being 30 to 60 minutes longer during the winter than in the summer, a result that is probably related to geographical position and lack of light in the winter.

At the end of the seventies, the Åkerstedt and coworkers carried out a series of studies on train drivers (Åkerstedt et al., 1980) in order to look at the impact of extremely irregular working hours on sleep, fatigue and well being. Particular attention was paid to the effects of age and supply work (and in particular the group of supply drivers who did not have a fixed work schedule – they were informed about their work hours only one day in advance).

The first phase involved a survey of almost 1,000 train drivers from different parts of Sweden. This showed that although the train drivers were satisfied with their jobs, the working hours and the physical work environment (mainly noise level, vibrations, inadequate maintenance and poor cab climate) were seen as a problem (Åkerstedt et al., 1980). There were also reports that the working hours intruded upon drivers' social lives and led to problems of sleep and fatigue.

Night and early morning shifts were associated with both short (approximately 4-5 hours) and restless sleep, extreme fatigue and even spells of micro-sleep (one to three seconds of deep fatigue and sleep) at work, problems which were more serious for older (>50) train drivers. Sleep following a night shift meant in particular that one woke up too early, while sleep before an early morning shift meant similar problems compounded by a fear of oversleeping. Overnight stays away from home were also disruptive to sleep and 81 per cent of the people interviewed believed that they slept worse when away from home.

Thirteen per cent claimed that they were dissatisfied with their working hours, which is relatively normal compared with other studies of regular three-shift work. It should be pointed out that for occupations requiring only daytime work (7.00 a.m. to 4.00 p.m.) the proportion of those who express dissatisfaction tends to lie below 5 per cent. The most unpleasant shifts were the night and early morning shifts, which were regarded as providing too little time for rest and recovery. The best shifts were those that started after 7.00 a.m. or that involved afternoon and evening work.

As regards the working conditions of the supply drivers, differences were relatively few compared with the permanent group. The supply drivers complained of greater disruption to their social lives, mainly in terms of planning their time off, caused by a lack of foresight in the scheduling. However, one problem with the methodology here was that the supply group was much younger, which made comparison with the group of permanent train drivers more difficult. It is therefore possible that any disparity between the two groups was concealed by their differences in age.

The project included two studies, which involved both physiological, and EEG measurements during work and during sleep before and after work. An EEG (which records the electrical activity of the brain) is considered the best measurement of the level of wakefulness, providing information on whether the driver had entered periods of micro-sleep during work. An EEG is also an excellent indicator of the quality of sleep and is used to assess its recovery value.

The first study (Torsvall, Åkerstedt & Gillberg, 1981) compared daytime sleep (before noon) following a night shift with night-time sleep before a day off, and found that the former period of sleep was three hours shorter (under five hours) than the latter. The older train drivers showed that although their daytime sleep was more restless (more awakenings) and included less deep sleep, it was not shorter.

Altogether, the study indicated that daytime sleep following a night shift was associated with a clearly inferior level of recovery and a considerable lack of sleep.

The other EEG study recorded the level of wakefulness on a daytime and nighttime run (Torsvall & Åkerstedt, 1987). The study revealed a significantly higher occurrence of serious sleepiness during night work; four of the train drivers (25 per cent of the participants) suffered frequent attacks of micro-sleep and had to make considerable efforts not to fall into continuous sleep. For some of these train drivers, their micro-sleep coincided with missed signals and ensuing ATC action. An analysis was also made of data gathered concerning train type (inter-city or freight), engine type, presence of ATC and age of the driver (Torsvall & Åkerstedt, 1982). None of these parameters appeared to have any bearing on the prevalence of sleepiness during night shifts.

All in all, Åkerstedt *et al.* (1980) recommended that greater attention should be paid in the scheduling to the consequences – increased sleepiness, lack of sleep and greater risk of driver error – of work and rest at different times of day.

At about the same time as the Åkerstedt study, Gerd Svensson at the National Board of Occupational Health and Safety carried out a smaller survey of train drivers' working conditions, including a thorough review of previous research within the field (Svensson, 1977).

The results of her report displayed a number of parallels with earlier studies, especially that the drivers perceive their physical work environment (primarily noise and vibration) and the working hours as seriously problematic. Her study also revealed dissatisfaction with the service and maintenance of the trains. The unpleasant scheduling also led to increased incidents of sleepiness and fatigue-related problems as well as stomach/gut ache.

She also gives an account of some comparatively early studies (foreign studies that were carried out in the sixties and early seventies) in which the researchers used heart rate during working hours as a measurement of physiological workload. These studies show a higher heart-rate when starting and stopping at a station and at the beginning of a shift, results which can be interpreted as a sign of increased stress and workload on the driver resulting from greater mental exertion (higher demands on concentration and alertness, large amounts of information to absorb, the frequent occurrence of poor visibility conditions etc). Extremely high readings (>100 beats/minute) were registered in situations when the driver was unsure about a signal (this was prior to the introduction of the ATC system), when technical errors arose, and when there were people near or on the track – probably from fear of hitting someone.

The report also includes a number of scheduling recommendations based on studies carried out on German train drivers. In general, these state that the effect of circadian rhythm on wakefulness and rest must be taken into consideration when planning the drivers' schedules (see Åkerstedt's recommendation above). Ideally, the scheduling should be worked out so that the shifts are as regular as possible and not too long (9 hours maximum). The need for an extra long rest period (minimum 24 hours) after a nighttime shift is also stressed. One interesting recommendation is that it should be easier for the train drivers to influence their own working hours.

During the seventies and eighties, Gudrun Hedberg (1987) of the National Institute for Working Life carried out a number of studies focusing on ergonomics. Concentrating mainly on health matters, her work looked at the role the driver's cab played in the development of workload-related injury and pain.

The latest major Swedish study was carried out by Kjell Ohlsson and is published as a VTI report from 1990. His study was based on observations made by the train drivers, interviews and a survey. However, as the survey had a high rate of non-response (70%) this should be interpreted with caution.

One of the main objectives of Ohlsson's work was to study what effect the ATC system had on the drivers' working conditions. He discusses the notion that train drivers nowadays rely on the ATC system rather than on external signals and speed-limit signs. A result of this is that the driver can relinquish control of the driving situation and take on a more passive role as a monitor, relying on the ATC system to cut in if a speed-limit sign or stop signal is missed (Johansson, Fredén & Ohlsson, 1988).

So although the ATC system is obviously an important tool for train drivers, it can, under certain circumstances, constitute more of a stress factor than a support for decision making. Research into stress and the nature of work shows that highly automated duties can be perceived as boring and non-stimulating, and can limit the operator's influence over the work he or she does (Gardell, 1986). This result in high levels of stress, reduced work satisfaction and less motivation (Karasek & Theorell, 1990).

Ohlsson (1990) shows, however, that most train drivers are relatively satisfied with the ATC system and that ATC events such as engine cutout and emergency brakes are rare. Many of the drivers do, nevertheless, consider that certain ATC functions are stressful when driving in the Stockholm region. Some commuter train drivers maintained that the combination of high-density train traffic and tight timetables and the pressure to avoid delay meant that they drive on the limits of acceptability. Several train drivers also report that they have missed signals in the Stockholm region during night shifts, although this is, in general, unusual. Many also thought that their working conditions became worse when they drove on railway sections where ATC was absent.

The study also shows that many of the train drivers have been involved in accidents or similar incidents, such as people throwing themselves in front of the train in order to commit suicide, collisions with wild animals, points accidents, vandalism or sabotage (objects being thrown at the train - this mainly applies to the Stockholm region).

Finally, this study too showed that irregular working hours was perceived as one of the most serious problems at work.

One of the worst causes of stress that a train driver can be exposed to is that of running over and killing or seriously injuring a person. Theorell *et al.* (1992) studied the stress reactions of underground train drivers that have run over someone (often cases of attempted suicide). The results show an increase in absence from work due to sickness, more sleeping problems, an increase in the level of certain stress hormones, and post-accident depression. In addition, these stress reactions were partially present more than half a year after an accident. Similar experiences were found in a Danish study (Beckmann, 1989).

Altogether Theorell's study indicates that a suicide-related accident can have a long-term detrimental effect on the health of the train driver. It is feasible that the stress reaction, e.g. as a result of the sleeping problems, can undermine performance and lead to reduced safety.

Foreign studies on the work environment of train drivers

During the seventies and eighties, a number of foreign studies were carried out those looked into train drivers' sleep and wakefulness in relation to their shifts. The results agree with the Swedish studies and show that sleep is disrupted and shortened prior of early morning shifts or after nighttime shifts (Foret & Lantin, 1972; Hak & Kampman, 1981). A Finnish study (Hannunkari, Järvinen & Partonen, 1978) and a Danish study (Netterstøm, Paludan & Laursen, 1981) also show that irregular working hours are a major problem for train drivers as well as their physical working environment. Safety, however, was not one of the features of these studies.

Davis (1966) compared 34 train drivers who had been involved in incidents (driving through a stop signal) with a control group of drivers whose work had been incident-free. The results showed that the former group reported more psychosomatic complaints and had been involved in more incidents on previous occasions than the latter. Just why the drivers complained of psychosomatic health problems was not discussed, but it is not unreasonable to put them down to work-related factors.

Austin and Drummond (1986) looked at the working conditions of commuter train drivers in Australia. Their results show that the main problem is inadequate safety measures; fatal accidents, vandalism and people on the track are common and also constitute serious problems for the drivers. A full 33 per cent claimed they had been involved in a fatal accident (usually by running over someone). Other, less serious work-related accidents included the driver slipping on the steps up to the driver's cab (17% reported that this had happened during the preceding week). Working hours, in

particular night shifts and long shifts following an early morning start were also a major problem. High mental demands at work, such as intense concentration and continual alertness, were also felt to be psychologically demanding.
Very few studies have looked into physiological workload and stress in connection with operating trains. A relatively new German study (Myrtek *et al*, 1994) has, however, examined train drivers' perceived mental workload and heart rate variability. They found that when driving monotonous stretches at high speeds, the drivers' heart rate variability decreased, something that is considered to be a sign of increased mental workload and stress.

However, the highest workload (both physiological and subjective) was apparent when arriving at or departing from a station. The authors reflected on the methods that should be used to study stress and mental workload at work. One conclusion was that not all variations in workload that take place during a shift could be obtained through subjective assessment and that a complete description of the workload should therefore also include physiological methods.

In the past few years, studies have been made into train drivers' working hours and workload in the USA and Australia. The Australian group has recently published their final report (Dawson *et al*, 1998), finding, as in previous studies, that train drivers suffer from severe fatigue and sleepiness when working at night. It is not at all uncommon for train drivers to skip sleep during the day (or take just a short nap) after a nighttime shift. Performance (tested with a 3 minute "tracking" test) was also at its lowest at around 2 to 3 a.m., while a short sleep (less than 5 hours), or a short period of rest before the shift, resulted in increased sleepiness at work. These last two factors had, however, far less an impact on sleepiness and performance than time of day.

The Australian study was also a major effort to improve the railway operators awareness' of how working hours impact on service. This included an extensive training programme (video, information leaflets, different presentation packages etc.) and a manual for the train drivers and their families. There was also a more comprehensive manual for key groups (e.g. industrial health personnel, safety representatives and personnel administrators) involved in issues relating to working hours and working environments. They have also begun work on a fatigue model, the purpose of which is to enable an evaluation of different timetables, in terms of sleepiness and workload, through reference to journey length, time of day, the preceding day's working hours and prior sleep.

There is also a Swedish/British fatigue model, developed by Åkerstedt and Folkard (Åkerstedt & Folkard, 1997). Besides assessing the level of fatigue, the model is able to predict the risk of accident, the risk of falling asleep etc., if the time is given for the beginning and end of the shift. This model is also under development and evaluation.

As far as we are aware, no official final report has been published of any similarly comprehensive American study. However, according to an abstract published at an international conference on working hours (Heitmann *et al*, 1997), while drivers have very strenuous (irregular and long) shifts, with regular micro-sleep events during the night, the problems of sleepiness and workload decreased when the drivers were given fixed schedules (e.g. when certain drivers worked night-time shifts only). They also recommend that train drivers be taught how to cope with irregular working hours.

In 1999, an American group presented a study on the effects of allowing the drivers to determine their own working hours. The results were positive, with an increased influence on the scheduling demonstrably reducing the level of perceived fatigue, which led to a longer period of sleep (Sherry, Heubert & Framton, 1999).

Accident studies: the effects of working hours, lack of sleep and sleepiness

Most studies relating to the train drivers' working conditions have focused on accidents, near-accidents and driver error. The most common error investigated was that of missed stop signals or speed-limit signs. A comprehensive report written by May and Horberry (1994) reviews these studies, a selection of which (based on the quality) we will now discuss.

Hildebrandt *et al* (1974) studied occurrences of emergency braking at different times of the day. One methodological advantage of this study was that their risk calculations took into consideration variations in traffic density over a 24-hour period. It was found that the risk of emergency braking peaked twice during the period: the first at 3 a.m., the second at 3 p.m.

The Hildebrandt study also analysed the variations over a 24-hour period in the occurrence of acoustic warning signals. An acoustic warning signal was heard if a SIFA pedal was not responded to within 25 seconds. (The SIFA pedal was a secondary task designed to prevent the driver from falling asleep). Incidents of these signals also peaked at 3 a.m. and 3 p.m. The authors argued that the greater risk of error at these times was due to increased sleepiness resulting from fluctuations in the circadian rhythm.

It was also found that there was a greater risk of such errors occurring when these critical times occurred towards the end of a shift, particularly the afternoon peak. This was interpreted as an indication that sleepiness accumulates during a shift. They also analysed the effect of rest periods on driver error, but no consistent pattern was found.

A Japanese study (Kogi & Ohta, 1975) has also analysed near-accidents/accidents and their relation to sleepiness, and found that approximately 17 per cent of incidents were sleepiness-related. The most common type of near-accident, which accounted for more than 50 per cent of incidents, was that of "unforeseen obstacles on the track", in which drivers come close to hitting passengers, track maintenance workers or other trains, for example. These near-accidents occurred mainly in the station areas, while incidents related to sleepiness occurred when driving along monotonous stretches of track. Sleepiness-related incidents were not related to weather conditions, the type of train or a particular stretch of track but were over-represented at night, with 79 per cent occurring between midnight and 6 a.m. One argument is that sleepiness-related incidents are caused by the combined action of a lack of sleep/insufficient rest and monotonous working conditions. One observation of interest was that train drivers also often reported a lack of sleep (the equivalent of about 50 per cent of drivers) in near-accidents that were not related to sleepiness.

Towards the end of the eighties, a Dutch study was published on driver error (missed signals) and working hours (van der Flier & Schoonman, 1988). This study analysed the occurrence of error in relation to the time-of-day, the month and other such situational factors. One advantage of this investigation was that they included data relating to traffic density. There was no indication that more signals were missed during the night, although there was, possibly, a slight increase during the start of the morning shifts between 6 a.m. and 8 a.m. There was no difference between weekdays and seasons.

However, one interesting observation was that the probability of error was highest during the second and third hour of the shift, to then drop towards the end of the shift - note, however, that during early morning runs the risk of error appeared to increase towards the end of the shift.

Error was more common in commuter train traffic than long-distance traffic, although the differences disappeared when adjustments were made for the fact that commuter train drivers were exposed to a greater number of signals.

A comparison was also made between drivers who were involved in situations of reported error and a control group of drivers who had not been involved in any incidents. The incident group was more dissatisfied (less motivated) with work and performed less well on reaction time tests.

van der Flier and Schoonman also discuss the reasons why more incidents of error occurred two to three hours into the shift, speculating that drivers might relax too much during the start of a shift. An alternative explanation is that such mistakes are due to fatigue accumulated from previous shifts. In this case, the accumulated fatigue would be the result of too short a rest period between shifts, which leads to insufficient sleep and recovery.

On the other hand, the results should not be over-rated as they could be random in nature and therefore purely coincidental. Opposing this claim are similar observations from other railway studies, both American and English, which found that the risk for accidents and driver error is at its peak from the second to the fourth hour into a shift and falls thereafter (Folkard, 1997; McFadden *et al*, 1997; Sparkes, 1994). These studies also were unable to provide a reasonable explanation as to why there is a peak during the first half of a shift. Folkard suggests that the phenomenon should be studied in controlled experiments in which rest patterns, work demands, shift departure point etc. is manipulated.

It should also be noted that train drivers can often spend the first hour at work running through a carriage check (brake tests, start up of ATC, etc). This means that the actual driving may well not start until the second hour of a shift, which could suggest that the accident problem is related to the fact that the driver is not sufficiently adapted (and perhaps not fully alert) to the driving. One interesting observation in the studies is that registered heart-rate frequencies were signs of high mental workload (faster heart rate) at the start of the shift (Svensson, 1977).

Sparkes' study (1994) reviews accident statistics based on data collected by British Rail. This study also showed no increase in risk of accident during the night (when adjusted for traffic density) nor during an intensive working week (>60 hours work). What they did find, however, was that the risk of accident increased somewhat on the first working day following a lengthy period of rest.

An interesting observation relating to accidents at night has been made in one American study (McFadden *et al*, 1997). They found that although the number of accidents was lower at night, the consequences of the accidents (in economic terms) were more serious. Whether this also applies to Sweden is not known.

Sparkes' results on behalf of British Rail would suggest that working hours have little impact on safety and accident risk. However, his paper was published in a conference proceeding and was probably not reviewed by an independent referee. In addition to this, Sparkes' paper neglects to analyse the causes of the incidents, and only considers working hours, leaving information on other environmental factors untouched. All this renders it difficult, therefore, to assess the actual quality of Sparkes' work.

It is also worth bearing in mind the inclination to submit reports. It is a well-known fact that minor incidents tend to go unreported, and there are suspicions that this is also frequently true of incidents that occur at night. It is possible that drivers are most reluctant to report sleepiness-related incidents, many of which can have serious consequences for the driver involved. Accidents often entail an investigation into whether the driver is suffering from any chronic sleep problems, illness, reduced capacity for alertness etc. If this is proven to be the case, the driver is likely to be re-assigned other tasks and barred from driving.

A recently published Australian study (Edkins & Pollock, 1997) has classified more than 100 railway accidents and near-accidents. The most significant accident factor in this study was the lack of alertness (e.g. meaning that critical signals were missed). They go on to discuss that this is probably related to the high degree of monotony in the train driver's work, ignoring any effects that working hours and other situational factors might have.

Edkins and Pollock also publish the results of a survey, in which it was found that motivation and morale were generally low among train drivers – and they concluded that this could also be an important cause of error. It is doubtful, however, whether these results can be generalised to Sweden.
Several empirical studies have shown that monotony is a risk factor leading to a reduced level of alertness (Nachreiner & Hänecke, 1992). The ability to remain alert decreases after about 15 – 30 minutes of work, while if a driver is already sleepy when starting his or her shift, this threshold shrinks to just a matter of minutes (Gillberg & Åkerstedt, 1998).

There are also some studies that look into case reports of train accidents and, for example, sleepiness. Two American accident investigators at the NTSB (the National Transportation Safety Board) have reported some very serious train accidents in which the driver had fallen asleep because of a strenuous schedule, an accumulated lack of sleep and, in certain cases, drug abuse (Lauber & Kayten, 1988).

Buck and Lamonde (1993) provide an overview of accident studies and the link between accident and fatigue. Advocating a need to study "natural" driving behaviour under realistic conditions rather than accidents and incidents, the authors argue that field studies can yield a good understanding of the causes of "spontaneous" near-accidents, error and mistakes. Errors occurring at work can be seen as critical situations, which, under "special" circumstances (e.g. unusual driving conditions, a particularly stressful shift or a driver's temporarily reduced operational ability) can become the cause of serious accidents. To analyse how the driver deals with his or her job under different working conditions can improve our knowledge of the mechanisms underlying accidents. Another advantage is that field studies make it easier to assess the effects of technical or organisational changes (e.g. when implementing safety measures), which is extremely demanding in terms of time and resources when employing accident data only. Naturally, there is nothing to prevent a combination of the different approaches and allowing both accident analyses and field studies to inspire each other.

Summary of earlier research

1) Working hours: Earlier research has highlighted above all the problems of irregular working hours. Night and early morning shifts are known to be associated with high sleepiness and inadequate recovery, but it is not fully clear whether this affects safety and leads to more accidents.

2) Physical work environment: Most studies have shown that train drivers feel that they have a strenuous physical work environment. However, it is doubtful that these results are representative of today's locomotives, which have come a long way, in terms of ergonomic design, since the end of the seventies.

3) Psychosocial work environment: Very little research has been done concerning drivers in this field, particularly in terms of safety.

4) Accident research: By far the most common method used is an analysis of surveys and registered accident data. A few studies have investigated physiological activity related to sleep/wakefulness and stress. One or two studies have analysed (logged) performance data and have made comparisons between different parameters, such as time of day. The results are not open to clear-cut interpretation.

5) Research relating to ATC: Virtually no research has been done on how ATC influences working conditions, with the exception of one investigation (Ohlsson, 1990). Since that study, however, the ATC system has been developed.

6) Total scheduling workload: As far as working hours are concerned, research has mainly concentrated on the workload related to certain shifts. There are no studies of the total workload of different working schedules (in terms of stress, sleepiness and sleep/recovery) and to see if sleepiness/fatigue can accumulate over several shifts as a result of insufficient intervening rest. One question of interest is whether an extremely heavy schedule (a dense schedule with frequent morning and nighttime shifts) can lead to chronic fatigue and burn out.

7) Individual differences: Some studies have analysed individual differences relating to involvement in accidents and near-accidents but without taking into consideration workload differences. As regards fatigue at work and sleep disturbance (in connection with different shifts), studies have focused mainly on the effect of age. There is a great need to improve knowledge in this field. What characterises train drivers who are seldom involved in accidents or mistakes at work? Do the differences depend upon the working environment (which leads to different working conditions) or how they cope with stress and irregular working hours?

8) Differences between different types of train traffic: One observation is that previous studies make no comparison between different types of traffic. Most of the earlier research is focused on long-distance and high-speed trains, while few studies have investigated commuter train traffic. The differences in traffic density (low versus high), stress, fatigue and safety have not been studied.

CAUSES OF SLEEPINESS, FATIGUE AND WORKLOAD

Working hours

The aim of this section is to explain why certain shifts - particularly nighttime and morning shifts – lead to problems with sleep and maintaining a high state of wakefulness. The section will also include research on other professional groups, but which is nonetheless relevant to this group.

It is a well-documented fact that shift workers, irrespective of their occupation, suffer from restless sleep and reduced wakefulness during periods of morning and night-time work (Åkerstedt, 1996). The majority fail to have more than about 5 hours sleep prior to an early morning shift (start before 6 a.m.) or following a nighttime shift. They found that the experienced quality of sleep is generally at its lowest in connection with early morning shifts, with most workers complaining of insufficient sleep, that they have problems with waking, or that they do not feel refreshed (Kecklund, 1996). The early morning shift is also related to an increase in sleepiness, with the decline in wakefulness during the afternoon being particularly noticeable (Kecklund, Åkerstedt & Lowden, 1997).

The most severe period of sleepiness occurs towards the end of the nighttime shift when involuntary drowsiness and micro-sleep events are not uncommon (Torsvall *et al*, 1989). Most shift workers have no trouble with evening work, as long as the shift is not prolonged or the individual is not suffering from a lack of sleep.

These results can be modified to a certain extent by the scheduling of shifts. It is assumed, for example, that feelings of sleepiness during night-time and early morning shifts become stronger if the shift exceeds 8 hours (Rosa, 1995). On the other hand, several studies have shown that the number of working hours has only minimal effects on levels of wakefulness (Lowden *et al*, 1998). One can presume that the nature of the work plays a decisive role here: work that is very demanding, both mentally and physically, and in which workers are unable to control the work-pace and rest periods themselves, is probably more sensitive to an extension of the shift.

One factor, which in several studies proved to be of greater importance than the number of working hours, is the length of the pre-shift rest period. We have observed that if, prior to a morning shift, this period is only 8 hours long, the length of sleep drops to about 4 hours and the quality of sleep is drastically impaired. On top of this, sleepiness at work increases dramatically, reaching the same levels as during a night shift (Lowden et al., 1998). Brief rest periods prior to an evening shift can also result in increased sleepiness.

Yet another important factor is the time at which the night shift ends and the morning shift begins. The earlier the nighttime work ends the better the sleep, and problems with micro-sleep and naps at work decline. This appears to apply particularly in the case of permanent night work (Gillberg, 1998; Kecklund *et al*, 1989; Wilkinson, 1992). On the other hand, early morning starts lead to greater sleep disruption and increased sleepiness for the shift in question (Kecklund *et al*, 1989; Gillberg, 1998). We have found that “evening” people find early morning shift work particularly difficult, as they already start worrying about their early and difficult morning rise during the evening, a concern which leads to an even more restless and disturbed sleep (Kecklund et al., 1997).

The order of rotation between shifts can also have a role to play. Some researchers argue that clockwise rotation, i.e. rotating from morning to evening and to night, improves shift worker’s capacity to tolerate irregular working hours (Knauth, 1993). The reason for this is that it is easier to adapt sleeping habits and circadian rhythms to the changing working hours. It also means that the rest period prior to an early morning shift is prevented from being too brief.

When discussing the effects of shift changes, it should be remembered that individual differences are great (Härmä, 1993). It appears that about 10 to 20 % of people who work irregular working hours find it difficult to tolerate shift changes, saying that they are much sleepier than otherwise and complaining of poorer sleep and health (Axelsson *et al*, 1998). Just why certain people have greater problems is unclear. One hypothesis is they cannot tolerate insufficient sleep and have a greater need of regular sleeping habits. When they are not working and can sleep normally, most of their sleep and wakefulness problems disappear and they return to a normal (low fatigue) state. There are also indications that the elderly (≥ 50 years) are likely to deal more poorly with shift changes, even though the data is somewhat inconsistent (Tepas, Duchon & Andrew, 1993). Older shift workers appear mainly to have difficulties sleeping during the day after having worked a nighttime shift.

Another interesting question concerns workers being able to influence and choose their own working hours. Train drivers at Hagalund apply a group selection system. These groups are separated according to traffic type (commuter trains only, high-speed trains, mixed group etc.) and scheduling, with the selection being made on the basis of seniority. There is much to suggest that people find it easier to tolerate shift work when allowed to choose their own working hours, even if there is relatively little empirical evidence for it (hardly any studies have investigated this issue). We have found that a high level of contentment with working hours is related to fewer sleep and fatigue-related problems for shift workers (Lowden et al, 1996). A worker’s ability to choose his or her own hours of work is believed to lead to a (more) positive attitude to the schedule. If this is true, this should be of benefit to the older train drivers (who have worked longest with the company and who have first choice), who should therefore adopt a more positive attitude to their schedules.

One interesting question is whether it is more difficult to deal with an irregular than a more regular schedule (e.g. a three-shift schedule, which regularly rotates between morning, evening and nighttime shifts). Findings here are exceedingly limited, but most experts believe that increased irregularity makes nighttime and shift work more difficult to tolerate.

The circadian rhythm

Problems related to shift changes are primarily caused by our biology, in that our circadian rhythm is set for rest and sleep at night and for activity and high functionality during the day. One additional factor, which is closely related to the circadian rhythm, is the lack of sleep. Social circumstances (family relationships, living conditions etc.) can also have a role to play.
Most features of our biological (e.g. hormones, body temperature) and psychological (e.g. level of alertness, mood, performance capacity) make up a pronounced circadian rhythm whereby activity is low at night and high during the day (Åkerstedt *et al*, 1979). For example, wakefulness (sleepiness) and body temperature levels reach their absolute minimum during the early morning hours, between 3 to 5 a.m., at which time our bodies are programmed to sleep and when it is most difficult to wake up (Dijk & Czeisler, 1995).

The circadian rhythm is controlled by a biological clock in the brain, which is sensitive to the changing patterns of light and darkness, in that darkness signals inactivity and rest while light signals activity (Czeisler & Dijk, 1995). Working at night is not sufficient to reset the circadian rhythm as, generally speaking, an individual is exposed anyway to sunlight (or is outdoors) during the day. In principle, if the circadian rhythm is to be re-programmed to reach high activity during the night, it is necessary to avoid light and the outdoors during the day, to change habits and routines from day to night-time, and to try and get as much exposure to strong light as possible during the hours of darkness. There are several laboratory studies where this has been tried and results show that most of the problems related to night work do then disappear (Czeisler et al, 1990; Eastman, Liu & Fogg, 1995). However, although very few investigations have run light tests under genuine conditions, a Norwegian study of shift workers on an oilrig did find that light facilitated both adaptation to night-time work and back again to the normal day-night rhythm (Bjorvatn, Kecklund & Åkerstedt, 1999).

Lack of sleep and length of time awake

In addition to the circadian rhythm, nighttime fatigue is largely the result of a lack of sleep. The longer you are awake, the sleepier you become, and most night workers have been awake for about 10 to 12 hours before starting their shifts. The length of time awake leads therefore to a drop of 10 to 20 % in wakefulness levels at the start of the shift and this reduction (= lack of sleep) continues to grow as the night progresses (Åkerstedt, 1995).

Nevertheless, a two-hour nap prior to the night shift greatly reduces the lack of sleep, which means that the most intense feelings of sleepiness of the early morning hours are avoided. To take a nap before a night shift is a better strategy for reducing sleepiness than trying to prolong night sleep into the morning by 1 or 2 hours.

There is also a lack of sleep prior to early morning shifts. The difference, however, is that this does not entail prolonged periods of wakefulness and that work is done during a period when the circadian rhythm is programmed for physical and mental activity. This means that most people do not suffer the same degree of sleepiness during the morning shift as during the night shift, with one exception being after a succession of several early morning shifts (or brief sleep periods). In laboratory experiments at least, sleepiness has shown to accumulate from day to day, and after about one week, levels are the same as during a night shift (Dinges *et al*, 1997). Naturally, this accumulative effect can also take place at night in cases of insufficient sleep between shifts.

Stress and mental workload

Above all, the actual job of driving a train generates a mental workload by virtue of the constant demands it places on the need to concentrate and monitor, and on the driver's readiness to handle unexpected operational conditions (e.g. technical disruption). Train drivers are also subject to stress arising from factors not related to the actual driving, such as working hours and lack of sleep. They can suffer from both physical stress (e.g. noise and vibrations) and psychosocial stress (e.g. threats of vandalism and violence, fast working pace and concern about accidents). In the following section, we will try to uncover the differences between the concepts of stress and mental workload.

Stress

The concept of stress has been developed within the fields of occupational and behavioural medicine and has mainly been employed in studies relating to health and well being. The concept is built upon three principal components: the environment or the demands of the situational context (the environment here is identified as the work situation); the capacity and resources the individual has for dealing with these demands; and the individual's physiological, psychological and behavioural reactions (Kalimo, Lindström & Smith, 1997).

Stress in its negative sense implies an imbalance between the demands of the environment and the capacity of the individual to cope, or that the individual's expectations exceed what is offered by the environment. In order to evaluate the consequences of stress, the individual's ability to evaluate and cope with the situation must also be taken into account. The stress reaction can be less severe if the individual can reinterpret the situation as non-stressful, or if there is a healthy social climate at work able to provide mutual support.

If a stress situation cannot be controlled, negative reactions arise such as discontent, worry, fear, frustration, and a lack of pleasure or motivation at work. Physiological responses, e.g. increased release of stress hormones, higher blood pressure, a more rapid heart rate, and a rise in blood fat levels are also linked to stress (Theorell, 1997). If this condition is allowed to continue over a period of time, stress can lead a state of exhaustion, burnout and illness. Suffering from burnout entails a constant state of physical and mental exhaustion or extreme tiredness. Burnout subjects experience feelings of being inadequate at work and that they are unable to satisfy their performance demands. It is not unusual that they go on to develop a cynical attitude towards work and perceive their jobs as pointless (Schaufeli & Buunk, 1996). However, stress is not only the result of workloads that are too heavy, but also of workloads that are too light. Denying an individual the chance to exploit his or her capacity and skills to the full often leads to discontent and stress.

There are therefore numerous factors and situations which can cause stress at work and some of the most common are difficult social relationships, problems with the organisation, poor career opportunities, strenuous physical conditions, excessive workloads and time pressure, demands that are too low (under-stimulation), little decision-making opportunity, no stimulation, lack of control and an inability to exert influence on the job.

When it comes to the monitoring of complex technical systems, any insecurity when confronted by unforeseen operational conditions can be a common cause of stress. This insecurity can arise from a lack of knowledge about how to manage a situation or the absence of feedback on whether measures that have been taken are correct or not. The situation described is an example of how someone lacks “cognitive” control over his or her performance, something which can lead to frustration and negative stress (Gaillard, 1993; by cognitive is meant “mental processes which concern thinking, information processing and decision-making”).

It is just this ability to control and influence one’s work situation that determines how serious the reaction to stress is (Karasek & Theorell, 1990). If it is possible to influence how the work is done, the extent of the job requirements and the length of the working hours (including when to take a break), it is easier to tolerate high work demands. Little potential for control and high demands increase the risk of developing cardiovascular diseases (Theorell *et al*, 1998).

Considering now the workload of the train driver, working hours can probably be seen as the most serious stress factor. The relatively limited opportunities to influence working conditions can also be a major source of stress. To this can be added other risk situations concerning stress, which today are quite common in normal working life: organisational cutbacks, poor management-employee relations and a more intense pace. If these factors are present, a fairly high degree of discontent with working conditions can be expected and, if they are allowed to continue for any length of time, a greatly increased risk of burn-out and illness as well. In all likelihood, such aggravated stress can also jeopardise safety.

Mental workload

If we are to study workload and stress and how these factors influence performance and safety, the medical view of stress is not the best one to use. A more meaningful strategy is to focus on the nature of the work and study how the mental workload is affected.

The concept of mental workload originates from the “human factors” field. It involves analysing the interplay between the capacity of the operator/individual, the demands of the job and of the ergonomic work environment. Mental workload is principally a matter of human mental abilities, of how information is received and processed, and the decisions and measures to which this leads. A high mental workload can result from an abnormally high pace at work, for example. Will the complexity or pace exceed the operator’s capacity?

One of the consequences of the increased technical complexity of present day working life is that while the demands on our thought processes and problem-solving abilities are higher than ever, the physical work requirements have been greatly diminished. If operators are working to the limits of their capacity, the likelihood increases that errors and mistakes will be made. And if this continues over a long period of time, there is considerable risk that conditions of stress will arise.

To be exposed to a high mental workload is not necessarily a negative cause of stress in itself. It is quite possible to do difficult and complicated work without being afflicted by emotional and health related complaints (Gaillard, 1993). High work demands can be dealt with by mobilising extra energy, which is expressed as mental effort. To mobilise extra resources is a normal and expedient strategy of adaptation to the demands of the situation. The negative consequence of this is mental fatigue. Fatigue can, however, also be something positive and the result of a very effective working day. Stress first appears when the balance between energy mobilisation and cognitive processes (effort) is upset, as a consequence, for example, of negative feelings (frustration, concern etc.) or of being unable or unwilling to mobilise additional resources (energy). In addition to the reactions mentioned above, stress in this context will lead to greater inefficiency and to problems recovering from work. (Gaillard. 1993).

A recently published study shows that the ability to mobilise extra forces is considerably impaired when a person is suffering from lack of sleep and after an extended work shift (Meijman, 1997). Once spare capacity was used up, performance also deteriorated. The most unfavourable situation arises when an extra effort has to be made because the job is unpleasant (either too difficult or too high-pace) and when capacity is reduced owing to difficult working hours (morning or night shifts or at the end of a long work shift) or a lack of sleep, for instance. Under these conditions, work capacity is greatly diminished, and extra effort can only probably be mobilised for brief periods only.

Methods for measuring mental workload are largely the same as those used in stress research. One example is the measurement of the heart rate. Other physiological methods, such as EEG (recording the electrical activity of the brain), EOG (recording eye activity) and EMG (recording muscular activity) can also, on certain occasions, give valuable information on the level of mental workload (Wilson & O'Donnell, 1988). The most common method, however, is some form of self-appraisal. Most of the self-rating scales include the components of time pressure, stress, degree of difficulty of the job, and (mental) strain (Tsang & Wilson, 1997). Although we have not found any study on the mental workload of train drivers, there are numerous studies that have registered workloads for other professions within the transport sector, for instance pilots and motorists, and analysed the impact of these workloads on performance and safety.

WORKING HOURS, STRESS AND PERFORMANCE

The circadian rhythm, lack of sleep and sleepiness influence performance ability. Cognitive functions (e.g. reaction time, vigilance and short-time memory) deteriorate late at night and when lacking sleep (Dinges & Kribbs, 1991). If a further lack of sleep occurs, performance levels deteriorate during the day as well.

Most studies looking into the relationship between performance and sleepiness have been conducted under laboratory conditions and with students or individuals lacking experience of shift work. There is much to indicate that the affects of sleepiness are less severe when carrying out realistic tasks, at least when studying individuals accustomed to working irregular hours. Whether or not task-impairment occurs depends largely on the nature of the work. The ability to drive a car or truck is an example of a task that is sensitive to the adverse effects of sleepiness and night work (Gillberg, Kecklund & Åkerstedt, 1996; Riemersma *et al*, 1977), while increased sleepiness also reduces performance for purely monitoring work (O'Hanlon & Beatty, 1977). Tasks that are exciting, active, stimulating and in which there is contact with other people are more resistant to the problems associated with a lack of sleep and sleepiness (Horne, 1988).

Studies of driver error and accidents have revealed that there is a distinct increase in the risk of accident when driving at night (Dinges, 1995), a finding that applies, above all, to motorway driving (Horne & Reyner, 1995). Analyses we have made of Swedish data show that the likelihood of a motorway accident almost doubles at night; singling out single-car accidents only, the risk is more than 10 times higher during the late night than during the day (Kecklund & Åkerstedt, 1995).

There is also a demonstrably higher risk of accidents at night in industry (Smith, Folkard & Poole, 1994). This also appears to apply to operator error (Bjerner, Holm & Swensson 1955: Folkard & Monk, 1979). Often, the increased risk of night-time error, accident and reduced performance is obscured as day and night work conditions are so different: at many work places the pace is slower at night, there is less operational disruption (e.g. from maintenance or repair work), and the work itself can be simpler. These factors can combine to reduce the amount of error and the number of accidents at night. Of course, it can also be the case that certain tasks are not sensitive to levels of sleepiness. Put simply, however, work that is solitary in nature and which places high demands on sustained vigilance and which is carried out in a monotonous and non-stimulating environment is the most sensitive to sleepiness.

When it comes to stress and performance, the nature of the research is more complex. Night work and lack of sleep are usually seen as contributors to stress, factors that often have the most tangible effects on performance. If such studies are excluded, one finds that that most investigations are conducted under laboratory conditions and frequently concerns the effects of some physical source of load (e.g. noise, vibrations and heat) on performance in a cognitive test (e.g. reaction time, perception or memory). Although performance is generally shown to deteriorate under these conditions, the extent to which this happens depends heavily on the nature of the task and how the physical stress factors have been presented (Hockey & Hamilton, 1983: Smith & Jones, 1992).

Psychological and psychosocial causes of stress, such as time pressure, high mental demands or lack of influence, are less common objects of study. Intuitively, it seems reasonable that too high work demands make it difficult to deal with complex tasks. It is precisely this phenomenon – that demands exceed an individual’s capacity and that this leads to error and mistakes at work – that has also been confirmed in many case studies (and in laboratory experiments) intended to measure mental workloads and performance (Tsang & Wilson, 1997).

There are also studies which show that reduced stress arising from organisational changes at work result in increased productivity (Karasek & Theorell, 1990), while empirical studies have shown that increased time pressure can lead to reduced productivity and performance (Zakay, 1993). A stress study carried out within the nuclear power industry showed that when work demands rose (increased time pressure and number of duties etc.) incidents of self-reported error increased (Kecklund Jacobsson & Svensson, 1997). Kecklund and Svensson also commented on the lack of field studies looking into the effects of working conditions on occupational error. Altogether, most of the evidence would indicate that stress has an adverse effect on performance and safety but that it is currently difficult to predict when, how and in what situations performance will deteriorate.

Strategies for coping with heavy mental workloads

A reason for why performance is often impaired by sleepiness or stress is that, under favourable conditions, many people are able to deal with moderate levels of sleepiness and stress by mobilising extra (mental) resources and focusing themselves on the task (Hockey, Wastell & Sauer, 1998; Schönflug, 1983, Meijman, 1997). This applies especially to tasks that are stimulating and varied and that do not demand too much time. By mobilising energy an individual can make a greater – mental - effort (focusing themselves) and thus counteract the effects of workload, albeit at the price of increased fatigue if the effort is made over a long period of time. There are also certain work situations in which this strategy must often be adopted to perform the task in hand, for example if the task is difficult and dealing with it places heavy demands on cognitive activity. Jobs involving several simultaneous tasks also often require extra effort in order to cope. If this strategy is successful – i.e. that the task is performed successfully with good results – then effort in itself poses no problem. But if the sleepiness or stress is serious, or continues over a long period, making an extra effort to maintain a high performance level probably does not help. In these situations it is normal to focus attention on the parts of the task which are most important and relegate other parts to a lower priority status (Hockey, 1997). This frequently results in the main task being performed relatively well at the expense of the secondary ones, which can then be subject to error and mistakes. On the other hand, the total negative effect on performance levels can be fairly moderate. However, such a strategy is risky if unusual and critical operational conditions arise and if the operator has problems redirecting his attention towards other solutions to the operational problems. Other strategies available to operators are to reduce their performance levels and to accept more errors and mistakes at work (Hockey, 1997).

On the whole, however, very little is known about the strategies people use for coping with high mental workload in real situations and how they influence performance and safety. Although a temporary high mental workload can be dealt with by mobilising more resources (energy), this is a strategy that probably only works for a few hours at a time, and it is unlikely that any “spare capacity” would be sufficient for an entire eight-hour shift.

Summary – the effects of stress and sleepiness on safety

There is good reason to assume that sleepiness and stress reduce a train driver’s mental capacity and when workload reach its peak, the demands on the driver can easily exceed his resources. However, individual differences are probably large and some drivers are able to tolerate greater workloads than others. One hypothesis is that the individual differences can partly be explained by the desire to put an extra effort into combating stress and sleepiness. An unwillingness to make an effort is possibly associated with a more negative attitude towards work and inadequate motivation. It is precisely these conditions which can appear as a result of adverse work-related stress.

But factors related to our biological make-up, our ability to tolerate sleepiness for example, can probably explain why certain individuals are more seriously affected by workload pressure than others. The possibility that stress and sleepiness work in unison can not be completely discarded either.

ACCIDENT ANALYSES RELATING TO WORKING HOURS, FATIGUE AND STRESS

Background and purpose

Earlier research on train accidents gives no clear picture of the effects of working hours and workloads on safety. The main purpose of phase 1 of TRAIN was to analyse the work situation factors relating to accidents and near-accidents.

We have analysed the investigations of 79 accidents and near-accidents provided by the project management. The investigations were carried out by SJ, although they are sometimes complemented by separate reports from the Swedish National Rail Administration and Swedish Accident Investigation Administration.

The selection of investigations was based on the following criteria: (1) that the train driver was involved in the occurrence of the accident or near-accident, and (2) that the investigation contained essential information regarding the cause of the accident.

The accidents occurred between 1980 and 1997. For a few years at the beginning of the 80s material is lacking, or the investigations do not fulfil the second selection criterion. Accidents caused by technical faults have been excluded. The investigations largely focus on the train driver's role in the events leading up to the incident; other key players, such as traffic controllers, are seldom included. The quality of the investigations varies widely, although it may generally be observed that there were considerable improvements in the 90s.

Most of the investigations relate to accidents and incidents occurring during the 90s. This should not, however, be interpreted to mean that more accidents occurred in the 90s – it is rather the case that incidents were more thoroughly documented during the 90s.

The object of the accident analysis was to examine the extent to which working conditions could have contributed to accidents or near-accidents. The factors we have studied are the influence of working hours (When during a shift did the incident occur? At what time of day?). Besides working hours we have tried to determine if fatigue and stress could have been involved in the incidents and whether there are any seasonal variations. With the aid of these analyses we hope to be able to determine how often a specific situational factor is present when incidents occur. However, the presence of one parameter, such as stress, at the time of an accident does not necessarily mean it was a decisive factor. The results should therefore be interpreted with caution - particularly as the investigations frequently contain relatively sparse information on the working conditions at the time of the incident.

Method

Most investigations lack information on whether stress or fatigue was involved at the time of the accident. On the other hand, all investigations contain information about when the incident occurred (date and, with a few exceptions, the time of day) and what type of incident it was (e.g. near-accident, passing a stop signal, derailment, collision, switching accident). Suicide accidents are excluded from the analyses. We have also compared incidents involving commuter trains with other types of traffic (mainly freight and long-distance traffic).

A few investigations indicate stress as a possible cause of incidents. But other investigations refer to lateness (=time pressure; note that this indicator is only mentioned if the train was more than 10 minutes late), which may be considered as a stress indicator. Indicators of suspected fatigue were one of criteria 1-3 in combination with criterion 4:

1) the driver admitted or the investigator observed fatigue
2) time of the accident (the incident occurred between 3.00 a.m. and 6.00 a.m.).
3) lack of sleep (less than 5 hours sleep) or a shift being preceded by a brief period of rest (less than 11 hours)
4) accidents or incidents characterised by missed signals, lack of attention or loss of memory. It is known that this type of event is frequently triggered by fatigue.

Below are a few examples to illustrate how we determined the existence of fatigue or not.

1) if the incident occurred at 6.00 a.m. yet the events surrounding the incident do not fit in with criterion 4) – not judged to be any suspicion of fatigue
2) as above but the driver reported that he nodded off or was sleepy – assessed as a fatigue-related incident
3) if the incident occurred at some other time than between 3.00 a.m. and 6.00 a.m., but the investigation indicated that there had been a short period of sleep, or that the rest period was so short that the previous sleep period must have been brief – it is judged to be a fatigue-related incident

This type of analysis to discover if fatigue was present or not, without doubt involves methodological shortcomings, possibly with the exception of criterion 1). On the other hand, the suspicion remains that drivers avoid reporting fatigue in view of the increased risk of negative consequences caused by fear of losing their licence. It is also doubtful if an individual is fully aware of his fatigue. In view of the previously mentioned methodological problems, we believe that our method probably gives a more correct picture than merely going by the driver's report (criterion no. 1). However, it should be pointed out that there is quite a serious risk of incorrect classification. Individual variations are rather wide, and some individuals can very well experience fatigue even after an extended period of sleep (e.g. due to sleep disturbance) and at times when the individual should be alert (e.g. due to a monotonous job). It is also a known fact that certain individuals do not get especially tired at night and cope relatively well with a moderately (1-2 hour) shortened period of sleep.

Results

Three (4 %) of the accidents were fatigue related according to criterion no. 1. However, this figure rose to 13 (17 %) if all the criteria were applied. It is interesting to note that we arrived at figures that were virtually identical to those in the Japanese study previously referred to (Kogi & Ohta, 1975), in which we also attempted to determine the occurrence of fatigue-related accidents. It ought to be pointed out that we have used a different methodology from that applied in the Japanese study. Studies of car accidents have shown that between 15 and 20 % of motorway accidents are caused by fatigue (Horne & Reyner, 1995; Maycock, 1997). Motorway driving is probably the type of car driving that most closely resembles the train driver's work. Five of the accidents where fatigue was suspected were due to a brief period of sleep after an extremely early morning shift, three were due to the driver being at the lowest level of the circadian rhythm, and two to a short rest period and in all likelihood a brief period of sleep.

If fatigue-related accidents are compared with other incidents, the comparison shows that the accidents where fatigue was suspected tended to be more frequent in the 80s (54 % versus 28 %, p=0.07), occurred more frequently during the dark months of the year (85 % versus 57 %, p=0.07) and involved missed signals (85 % versus 58 %, p=0.07). However, there are no statistically reliable differences, when it comes to ATC problems, between fatigue-related incidents (18 %) and other incidents (31 %).

A further fatigue-related accident that occurred can to a high degree of certainty be identified in the material, but in this case it was not the train driver who was sleepy. This incident involved a train colliding with a truck. The truck driver satisfied several of our fatigue criteria (but not criterion no. 1).

Three (4 %) of accidents were associated with suspected stress, which was largely the result of private problems. If we also include incidents involving lateness, the number rises to 11 (14 %). It is interesting to note that in 10 of these incidents fatigue was not suspected.

Most of the accidents – 67 % - occurred in the 90s. Commuter trains were involved in 18 % (n=14) of the incidents. About one fifth (16) reported the existence of slippery conditions, snow or ice. In 6 % (5) of the incidents the driver reported that he had been blinded by sunlight. The most common type of accident was derailment (37 %), followed by near-accidents (28 %), collisions (25 %), switching accidents (6 %) and others (4 %). In sixty three per cent of the incidents the driver passed through a signal in stop position or a speed reduction signal. Slightly fewer than one-third (29 %) had reported ATC problems, mainly that the driver had misunderstood ATC information.

In table 1, we have compared commuter train accidents/incidents with other accidents in relation to different work characteristics.

Table 1. Comparison between commuter train traffic and other traffic (long-distance, freight train etc.) with regard to factors involved in accidents or incidents (n=79).

	Commuter train	Other traffic	p-value
Incidents during the 90s	64 %	68 %	n.s.
Near-accidents	43 %	25 %	n.s.
Derailment	43 %	35 %	n.s.
Collision	14 %	28 %	n.s.
Missed signal	86 %	58 %	0.05
Speeds too high	20 %	36 %	n.s.
Lateness (at least 10 minutes)	0 %	33 %	0.02
Fatigue suspected	43 %	11 %	0.004
Age of driver	39 (3)	42 (1)	n.s.
Time of incident (hours, minutes)	12.47 (1.40)	11.42 (0.42)	n.s.
Incidents during morning shift	46 %	56 %	n.s.
Time after start of shift (hours, minutes)	3.20 (0.36)	4.13 (0.41)	n.s.
October –March (dark season)	71 %	60 %	n.s.
Slippery conditions, snow or ice	7 %	23 %	n.s.
Driver blinded (by sun)	0 %	8 %	n.s.

n.s.=non significant, means and standard error of the mean (within brackets)

When the mean value is given, the standard error of the mean is stated (dispersion measure) in brackets. The p-value is a measurement of whether the differences are statistically confirmed – the lower the value, the greater the likelihood that the difference is significant (n.s. = not significant, i.e. the difference is due to chance, the limit for when a difference is statistically significant is when the p-value is 0.05 or lower).

We found three statistically reliable differences: in the case of commuter train accidents there was a higher frequency of missed signals and suspicions of fatigue, while the cause “delay” (which was a stress indicator) was less frequent. In the case of other factors there were no differences between commuter trains and other traffic. However, it should be pointed out that the number of commuter train accidents is very low, which makes statistical analyses uncertain. The results should therefore be treated with great caution. If, despite this reservation, one attempts to draw any conclusions, the results suggest that commuter train driver’s experience more problems relating to lack of alertness and fatigue than drivers in other types of traffic. However, it should also be observed that the number of signals to which commuter train drivers have to react is far higher. Nor can we exclude the possibility that commuter traffic involves other working hours than for other types of traffic and consequently more fatigue.

The difference with regard to lateness/delays is hard to interpret. One possible explanation is that delays of more than 10 minutes means less in commuter traffic as the trains run so frequently. Furthermore, it is reasonable to suppose there is less chance of making up for delays in the case of commuter trains. It is also possible in the case of commuter traffic to introduce reserve trains when delays exceed 15 minutes.

Figure 1 illustrates the distribution of accidents and incidents by time of day. There are two peaks – around 9.00 a.m. and 5.00 p.m. The occurrence of incidents is at its lowest in the evening (between 10 p.m. and midnight) and at night (between 2.00 a.m. and 6.00 a.m.) Twelve per cent of the incidents occurred at night, between midnight and 6.00 a.m. Rather more than half (54 %) of them occurred during morning traffic (starting before 9.00 a.m.).

As the number of accidents is low, these results should be interpreted with caution. Moreover, we have no information about traffic intensity and therefore cannot calculate any figure for risk of incidents. Probably traffic intensity is highest when accidents are at their peak in the mornings and early evenings, and is lowest at night.

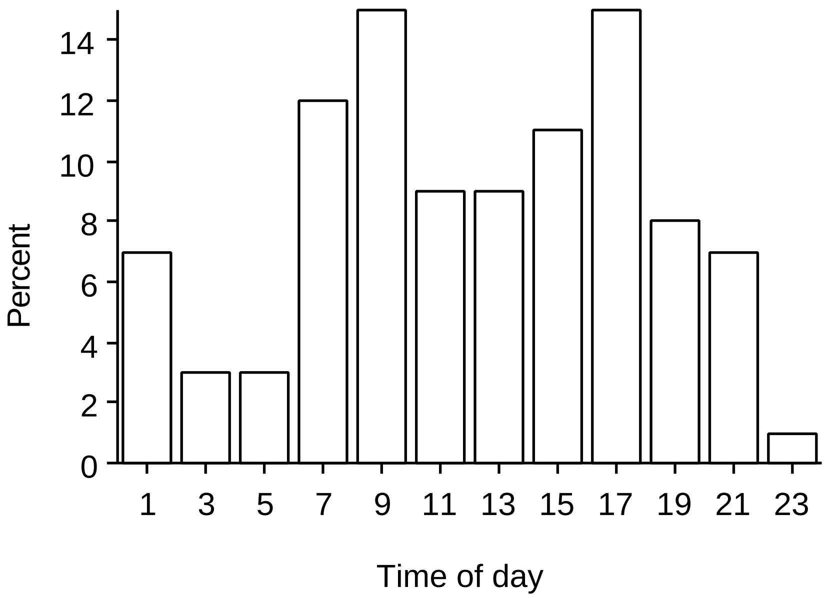

Figure 1 illustrates the time of day (in two-hour intervals) when accidents or incidents occurred (n=79).

Figure 2 illustrates seasonal variations in the occurrence of accidents and incidents. Most incidents (62 %) occurred during the dark winter months, defined here as

October through March. In the figure below the distribution is shown by month. The most incident-prone month is February, followed by December and September. However, as no data are available for seasonal variations in traffic intensity, it cannot be concluded that there is a higher risk of incidents during the dark winter months. If traffic density is higher at this time of the year, this could well explain the variation in accident rates.

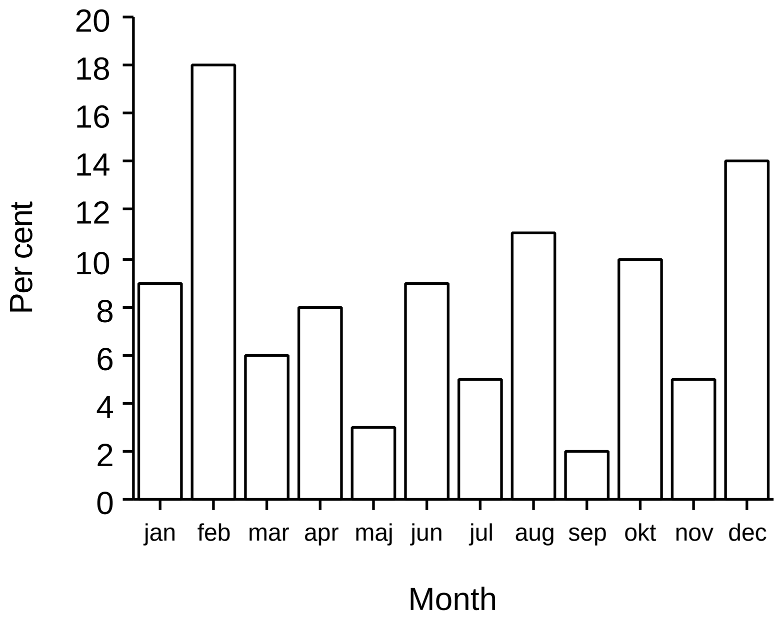

Figure 2 illustrates seasonal variations in the frequency of accidents and near-accidents (n=79).

Complete information regarding when the shift started is available for 20 of the incidents. The results of this analysis are illustrated in Figure 3.

As in previous studies (e.g. Folkard, 1997), we found that the occurrence of accident/incidents increases up to the third hour of the shift, and then falls. Seventy five per cent of the accidents occurred during the first three working hours (a more exhaustive discussion of this phenomenon is provided in the section entitled “Accident Studies”). However, it should be noted that the sample is very small and there is serious risk that chance has influenced the result. It is reasonable to suppose that very few shifts indeed are shorter than 3 or 4 hours, although we do know that relatively many shifts are shorter than 7 hours. If it had been possible to calculate the risk of an accident occurring (i.e. take into account the number of shifts that are at least 3, 4, 5 6, etc. hours long), the peak after 2-3 hours would probably be considerably lower, while the risk of accidents after 6-7 hours would be higher.

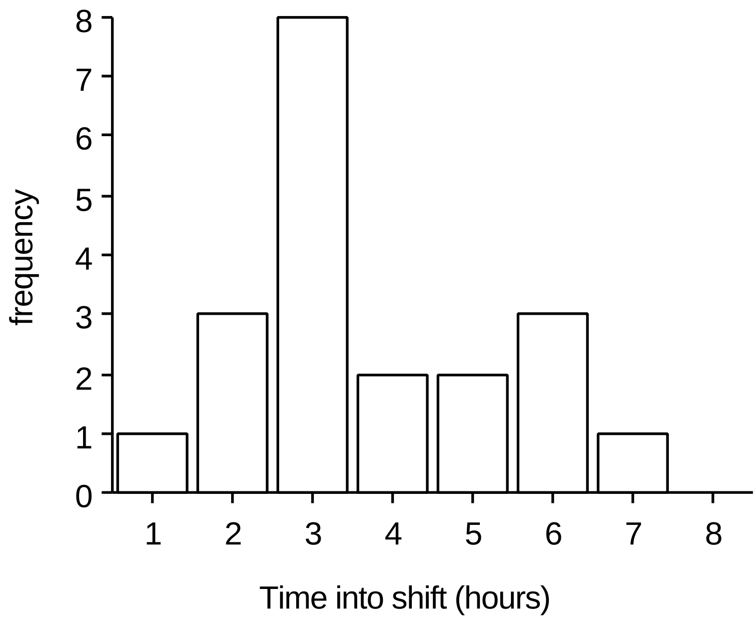

Figure 3 illustrates how long into a shift accidents/incidents occurred (n=20).

Summary

It is difficult to arrive at any definite conclusions from this analysis of accidents and incidents, mainly because of the small size of the sample. The absence of data on traffic intensity also prevents one from correctly interpreting several of the analyses. A further shortcoming is that the work situation factor was not generally investigated (or the quality of the investigation was inadequate with regard to these factors) in the accident investigation. However, the results indicated that the relative level of accidents due to fatigue appears to have declined during the past 10-year period. It is reasonable to suppose that the reduction is a result of ATC eliminating some of the effects of fatigue at work. Possibly the differences between commuter train traffic and other traffic could also be interest. The continuation of the study will probably provide an answer to the question of whether commuter traffic involves greater fatigue and a higher risk of driver error than other types of traffic.

On the basis of our conclusions we recommend that SJ and other traffic operators obtain more information about working conditions in connection with their investigations of accidents and incidents. As far as working hours and workload are concerned, information should be obtained on the situation prevailing for at least one week prior to an accident (and preferably enclose the schedule of the driver involved for at least 4 or 5 weeks). Had he/she worked overtime? Was the driver in a scheduled period with a heavy workload? Were the periods of rest between shifts, and the rests and breaks provided in the timetable, sufficient? Did the previous shift involve a great deal of stress? With this information it should be possible to quantify how much the driver worked (and how much stress the workload involved) during the previous week, for instance. Without this information it is hard to determine whether the work situation was a significant factor behind the accident. More information should also be obtained regarding the private situation of the driver(s) involved, such as stress in private life, extra work and life style.

The question of whether fatigue and sleepiness, stress and workload were too high in connection with an accident is a sensitive topic for the driver. It can be supposed that drivers avoid reporting these phenomena, in view of the possible consequences in the form of medical examinations and various psychological tests to determine if the driver should be allowed to keep his train driver's licence. An important factor in this context is company's safety awareness and attitude towards errors, accidents and the work environment. If the company is aware that serious fatigue and stress are natural conditions that can affect everyone (on odd occasions) with irregular working hours and a high workload, drivers will be more willing to admit that they were stressed and/or sleepy. It is probably also easier to introduce measures to improve safety if there is an openness and understanding that working conditions will influence performance. One strategy to stimulate the willingness of drivers to report fatigue, stress and lowered performance levels, etc. could be to provide total anonymity.

One step in the right direction is to develop more in-depth analyses of accidents to enable the driver's behaviour and actions in an accident situation to be better understood. If accident investigations are extended to include an assessment of the effect of working conditions on incidents, this will greatly improve the ability to study the effect of the work organisation (e.g. reduced manning, changes in working hours) and technical changes on traffic and driver safety.

DESCRIPTION AND ANALYSIS OF TRAIN DRIVERS' WORKING HOURS

The first step in an analysis of shifts is to define the meaning of shift. In most cases it is fairly easy to recognise when a shift starts and when it ends. Often, a shift is defined by means of a schedule listing different shifts, and indicating starting and finishing times as well as periods of rest between shifts. Train drivers' work schedules often extend for periods of four or five weeks, unless they belong to a reserve group. Duties are indicated in a schedule and consist of a sequence of tasks (e.g. train service, duty trips, on-call or reserve) and off-duty time (e.g. leave on 100 %, 25 % or 0 % pay plus leave of absence i.e. lengthy periods in another district). The duty roster gives an incomplete definition of a shift as it is limited to the start and finish within a single 24-hour period. Should the service continue after midnight, there is a new roster for the following day, which follows on where the old one leaves off. Another problem is that a duty schedule can include one or more lengthy breaks. There are several examples of schedules including breaks of longer than five hours. In such cases there is little point calling it a shift, as it is obvious that it involves a split schedule with two periods of work and free time in between.

In the following analysis, the duties are shown in the same sequence found in each time schedule. The start and finish of the shift is determined by how much free time there is between periods of work. When the off-duty break lasts for at least three hours, the shift is regarded as ended. The exception is off-duty breaks with full pay. The idea is that a shift shall state the time when the train driver is mainly bound to his place of work (including breaks) with little if any opportunity for activities away from his place of work.

At Hagalund, in an average week there are a total of 1,290 shifts, allotted to 274 train drivers with a fixed work schedule. An average working week consists of 4.7 shifts of 7.6 hours with 28 hours of free time interspersed between the shifts. A shift has an average of 0.9 scheduled breaks and when this time is deducted, the working hours averages 6.9 hours per shift. A typical shift lasts for between 7.5 and 9.25 hours (figure 4). There are cases of exceedingly short shifts of less than 4 hours and very long ones of more than 12 hours. Typically, a free period is between 10 and 12 hours (see figure 4).

Closer examination of the long shifts of 12 hours or longer (n=41) shows that a relatively large proportion of them (18=43.9 %) consist largely of on-call time. The share of on-call time is otherwise marginal (59=4.6 %) in comparison with the total number of shifts. On-call time involves a relatively high state of preparedness to assist when needed, during which the train driver is confined to his place of work with rather limited freedom. Another type of contingency is reserve train duty, which means remaining close to a train, in full running order, ready for immediate service if and when needed. Shifts consisting mainly of reserve train duty represent a marginal share (42=3.3 %) of the total number of shifts. The average length of shifts with on-call time is around 9.8 hours, which is significantly ($p<0.001$) longer than a shift with normal service or reserve duty (7.5 and 7.6 hours respectively).

The shortest shift of less than 4 hours (56) is separated from another shift by 5.5 hours on average, which means relatively many split shifts.

A train driver’s shift can start more or less at any time of the day. There is a marked peak at 5 o’clock in the morning and another in the afternoons between 1.00 p.m. and 3.00 p.m. A few shifts begin between midnight and 3.00 a.m. The ends of the shifts are relatively uniformly distributed over the day. However, there is a peak just before midnight. Few shifts end between 3 o’clock and 6 o’clock in the morning (figure 4).

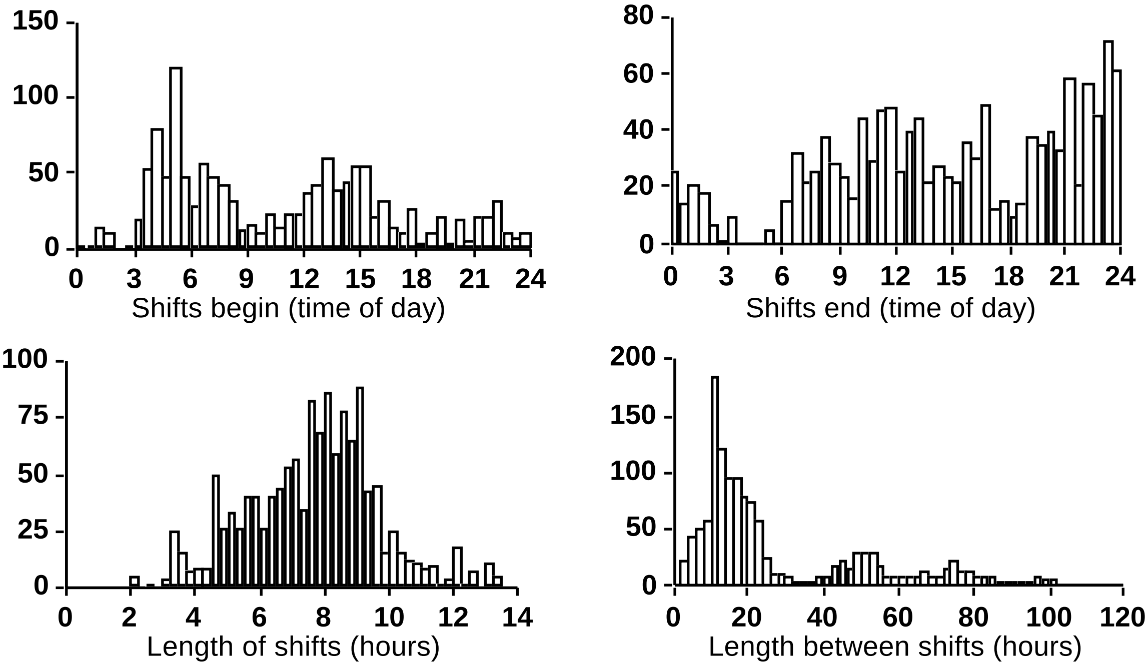

Figure 4. Distribution of length of shifts, length between shifts (off-duty periods), beginning of shifts and end of shifts (n=1290) for 274 train drivers with a fixed schedule, during an average work week.

Figure 5 shows the distribution of train drivers on duty during the day for all weekdays. The number of train drivers on duty is at its lowest during the night (at about 3.00 a.m.). However, it should be noted that relatively many train drivers have off-duty time (i.e. a break on full or 1/4 pay or absence from home) during the night. It is difficult to assess the importance of a break at night. Probably, most of the drivers do sleep during these absences from home, at least if the conditions are reasonably conducive to sleep. If a break is long enough, it might be suspected that many of them take a nap. An important factor in this context is the physical conditions for sleep. If these conditions are poor one simply avoids trying to sleep. At present, we do not know how many of them go to sleep or how they sleep during breaks at night. This issue will be examined in the next phase of the project. It is also worth noting that the frequency of night duty is slightly lower at weekends.

There is a sharp rise in the number of train drivers on duty late at night (very early in the morning). At 6.00 a.m. on a weekday morning, about 80 train drivers are on duty and a few hours later there are another ten or so. Two distinct peaks can be noted: one in the morning and one in the afternoon. However, this pattern can only be seen on weekdays. At the weekend, these morning and afternoon peaks disappear.

As far as workload is concerned, it is important to study the components of shifts over a 24-hour period. One point of particular importance is the influence of working hours on the normal circadian rhythm of wakefulness and sleep. For this reason, the shifts are divided up by type, namely morning, day, evening and night shifts. The criterion for a night shift is based on the fact that a night shift usually delays the normal main period of sleep. In the analysis below, shifts that finish after 1.00 a.m. or begin before 3.00 a.m. are defined as night shifts. The definition of evening shift is based on the fact that shifts of this type encroach on a normal evening rest; it consists of shifts that end after 8.00 p.m. but before 1.00 a.m. The criterion for a morning shift is that is begins no earlier than 3.00 a.m. and no later than 6.00 a.m., which in most cases probably means getting up early. All other shifts are defined as day shifts.

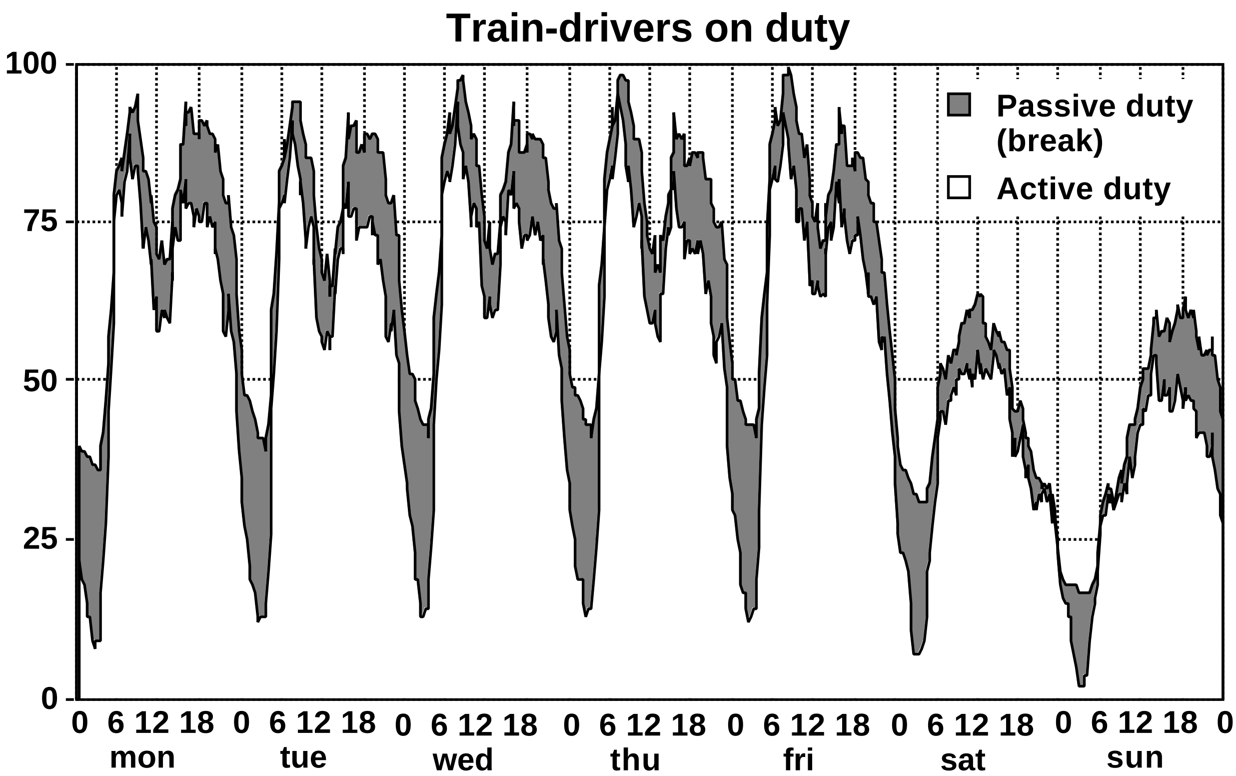

Figure 5. No. of train drivers on duty (n=274) at different times of the day, by day of the week. The figure shows active duty and passive-duty(breaks) periods.

Table 2 shows the distribution of shifts by type. The most common are evening shifts (33 %), and then morning shifts, which represent 28 % of the total number of shifts. A variance analysis shows that the different types of shift differ for all variables in the table (p<0.001). The night shift is the longest and the morning shift the shortest. The difference is still observable even when breaks (off-duty time) are deducted. The evening shift has the shortest period of free time after work, and the morning shift the shortest period of free time before work, which is reflected in the high proportion of shifts with rest during the night. The period of off-duty time is longer after morning shifts, while the longest period of free time is found before work on the evening shift. This indicates that long breaks often start after the morning shift and end when the evening shift starts.

Table 2. The number and length of shifts, and actual working hours plus the length of free time before and after, by morning, day, evening and night shift.

Type of shift	N	%	Length	Of which working time	Free period before	Free period after
Morning	366	28.4	6.78±0.1	6.19±0.07	17.43±0.80	43.50±1.31
Day	318	24.6	7.70±0.1	6.99±0.09	20.85±1.07	21.90±1.15
Evening	429	33.3	7.93±0.1	7.14±0.08	39.75±1.27	15.00±0.50
Night	177	13.7	8.65±0.2	7.47±0.16	34.50±1.92	38.70±2.06
Total	1,290	100	7.64±0.1	6.88±0.05	28.04±0.66	28.04±0.66

The table shows the mean value in hours ± 1 standard error of the mean

The train drivers at Hagalund with a fixed time schedule can be divided into three large groups and one small group. Drivers in the commuter train group (n=60) only drive commuter trains. There is a mixed traffic group (n=115), whose drivers drive both long-distance and commuter trains. There is another group (n=80) of drivers who also drive the X-2000 (high-speed) train. The others (n=19) are a very heterogeneous group who work according to special schedules with mainly night, morning, afternoon or weekend duties. The remaining drivers belong to the reserve group. They do not have a fixed schedule, and have (for obvious reasons) been excluded from the analysis.

A chi2 test shows that the pattern of shifts differs (p<0.0001) when the scheduled groups are compared with each other. The “Other” group has relatively few day shifts but a high proportion of morning, evening and night shifts as these schedules are specifically designed for this type of shift. Its low share (7.3 %) of night shifts and relatively many day shifts in relation to the commuter train and mixed traffic groups distinguishes the X-2000 group. In relative terms, the mixed traffic group has fewest morning shifts (table 3).

Table 3. Distribution of shifts by four different schedule groups.

Shift type	Mixed traffic		Commuter train group		X-2000 group		Other	
	N	%	N	%	N	%	N	%
Morning	137	25.6	82	30.7	115	28.8	32	36.0
Day	136	25.4	58	21.7	118	29.6	6	6.7
Evening	174	32.5	86	32.2	137	34.3	32	36.0
Night	88	16.4	41	15.4	29	7.3	19	21.3
Total	535	100	267	100	399	100	89	100

Table 3 shows the number of work shifts and the percentage breakdown into types of schedule.

With reference to time away in another district between work shifts, there is also a considerable difference between the different schedule groups (p<0.0001). In the X-2000 group, 43 % (170) of the shifts involve absence before or after a shift; this may be compared with 10% for the commuter train group (26), and 28% (152) for the mixed traffic group. In the Other group, the proportion is 20% (18).

Table 4 shows the breakdown of shifts that are preceded by a period of free time outside home of residency (labelled absence) by group and during a 24-hour period. The commuter train group only has absence during the night before a morning shift. The period of absence is also shorter than in the case of the X-2000 group and the group driving in mixed traffic. This means that the drivers belonging to the commuter train group work until later at night and/or start earlier in the morning, which gives a shorter period of night rest before the morning shift. The high average duration (8.1 hours) of the absence before a day shift in the X-2000 group is largely due to the period of absence being at night and to the next day's work starting after 6.00 a.m. and being classified as a day shift. But the X-2000 group and the mixed traffic group also have longer breaks (over 3 hours) that involve being away during the day and afternoon ending with a day, evening or night shift.

Table 4. Number of shifts with absence (preceding free time outside home of residency) by type of shift and schedule group. The means show the duration of free time before the shift..

Shift type	Mixed traffic	Commuter train group	X-2000 group	Other
Morning:				
N	35	13	43	3
Means±se	7.01±0.33	5.80±0.56	7.36±0.29	4.56± 0.11
Day:				
N	20	0	23	0
Means±se	6.93±0.47	-	8.12±0.44	-
Evening:				
N	2	0	13	1
Means±se	3.07±0.00	-	4.20±0.12	3.28±0.00
Night:				
N	19	0	6	5
Means±se	8.26±0.69	-	8.49±0.29	5.10±1.89
Total:				
N	76	13	85	9
Means±se	7.20±0.28	5.80±0.56	7.16±0.24	4.72±1.02

Table 5 shows comparisons between the schedule groups for selected variables. A variance analysis shows that there are differences between the groups in terms of the longest unbroken period without a break and the number of breaks per shift ($p<0.0001$). On the other hand, differences in the total length of the shift or the amount of work it includes are not significant. On average, the X-2000 group has the longest continuous shifts without breaks for rest, and the commuter train group has most breaks per shift.

Table 5 Length of shift, proportion of work, number of breaks and longest continuous period without a break by schedule group.

Variable	Mixed traffic	Commuter train group	X-2000 group	Others
Duration	7.53±0.09	7.84±0.09	7.69±0.12	7.57±0.23
Of which work	6.84±0.07	6.98±0.08	6.99±0.10	6.77±0.19
Number of breaks	0.83±0.03	1.19±0.04	0.79±0.03	0.90±0.07
Longest continuous period without a break	4.58±0.07	4.18±0.06	4.92±0.09	4.47±0.19

The table shows the mean value in hours ± standard error of the mean

All in all, it may be observed that the schedule groups often have early morning shifts (more than one shift per week on average) and short periods of rest (less than 16 hours) between shifts. The total workload time, however, is relatively similar for all groups. However, the workload profiles of the different groups vary. The commuter train group and the mixed traffic group work more night shifts than the X-2000 group. The X-2000 group, for its part, has to work more shifts that are preceded by short periods of rest (combined with absence) than the other groups, which leads to more split shifts. The greatest difference is found in relation to the commuter train group. However, the X-2000 group has more early morning shifts, preceded by brief periods of rest, plus fewer breaks per shift. The X-2000 group also has the longest period of work without a break.

One conclusion from the above analyses is that the scheduled groups' workloads are largely due to early morning shifts and nightshifts. The X-2000 group has relatively frequent, short periods of rest (and split duties) between shifts and rather fewer breaks than the other groups. The mixed traffic group's workload profile lies somewhere in between the other groups and involves a mixture of night and early morning shifts, and shifts with short periods of rest.

CONCLUSIONS

A review of the literature shows that relatively little research has been carried out into the working conditions of train drivers. Many of the studies date back 20 years or more and it is doubtful whether their findings are relevant to today's working conditions. Furthermore, early research tended not to focus on safety, performance and ATC.

Accident analyses were limited by the relatively low number of accidents that we could investigate and by the fact that most investigations lacked information on working conditions (workload, working hours, etc.) at the time of the accident. However, we did find that in 17 per cent of the accidents, there were suspicions of sleepiness (in 4 % of the accidents the driver admitted to having felt sleepy when the accident occurred). Stress relating to private life, or as a consequence of delays, was present in 14 per cent of the accidents. In the case of commuter train accidents the proportion of accidents where sleepiness was suspected was even higher. In view of the methodological shortcomings, caution should be exercised when drawing conclusions from the above results.

Finally, an analysis was made of the timetables for train drivers at Hagalund. The analysis showed small differences in the total workloads of commuter train drivers, X-2000 drivers and drivers in mixed traffic. On the other hand, the workload pattern varied for the individual groups. Commuter train drivers and those in mixed traffic had more night duty, for instance, whilst the X-2000 drivers had more trips preceded by brief rest periods and fewer breaks per shift.

In the next phase of TRAIN, a questionnaire will be sent to all train drivers at Hagalund. A small group will be studied in detail with the focus on workload, stress, sleepiness and recovery (sleep) and what effect these factors have on safety and work performance. Work with data collation has been in progress since the spring of 1999. It is estimated that the results of the questionnaire will be available during the autumn, while the report on the logbook study is expected to be officially released during the spring of 2000. Phase 3 of TRAIN, in which we will focus on proposals to improve the working conditions of train drivers, will begin in 2000.

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