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Hours of service regulations and the risk of fatigue- and sleep-related road accidents

A literature review

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Summary:
Research has demonstrated impaired driving performance with increasing driving time. About one-half of truck-drivers in one study reported episodes of falling asleep while driving. The crash risk tends to increase with driving time, especially after 9-11 hours. The amount and quality of sleep before driving seems to have a stronger effect than driving time on performance and risk. There is a clear scientific rationale for regulating resting and driving periods. Violations of hours of service regulations are frequent, too short rest periods between working periods being an especially common violation. Low compliance seems to be partly due to complex regulations. Harmonization across countries concerning interpretation of the regulations, tolerance levels, and sanctions, as well as increased level of surveillance is likely to result in increased compliance and safety. The role of transport companies in promoting safe driving should also be focused.

Tittel: Kjøre-og hviletidsbestemmelser og risikoen for trafikkulykker relatert til trøtthet og søvn. En litteraturstudie.

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Sammendrag:
Forskning viser redusert kjøreferdighet med økende tid bak rattet. I en undersøkelse hadde omtrent halvparten av tungbilførerne opplevd å sovne bak ratet. Ulykkesrisikoen øker med økende sammenhengende kjøretid, spesielt etter 9-11 timer. Mengde og kvalitet av søvn før kjøringen ser ut til å være viktigere enn tid bak rattet når det gjelder virkningen på kjøreatferd og ulykkersiriko. Regulering av kjøre- og hviletid har et klart forskningsmessig grunnlag. Overtredelser av regelverket for kjøre- og hviletid skjer ofte, spesielt når det gjelder bestemmelsen om døgnhvil. Lav overholdelse ser delvis ut til å henge sammen med at regelverket er komplisert. Harmonisering mellom landene når det gjelder fortolkning av regelverket, toleransegrenser for overtredelser, og straffenivå, så vel som økt overvåking, vil kunne bidra til bedre overholdelse og sikkerhet. Transportbedriftenes rolle når det gjelder å påvirke og motivere førerne til sikker kjøring bør også fokuseres.

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Preface

Although heavy goods vehicles and buses do not have a higher accident risk than other vehicles, the accidents involving such vehicles are often more severe than other accidents. Reducing the accident involvement of heavy vehicles is therefore important in order to reduce the number of fatalities and severe injuries in road traffic. A measure with a potential to reduce the risk of accident involvement for heavy vehicles is the regulation of hours of service. This measure regulates the length of resting and driving periods, both in order to prevent fatigue- and sleep-related accidents with heavy vehicles, and to assure equal terms of competition in road transport between companies and countries. The present report is an assessment of the traffic safety implications of regulating the hours of service, based on a survey of research literature.

The study was commissioned by the Swedish National Road Administration, and Sofia Gjerstad has been their contact person for the project.

At the Institute of Transport Economics Astrid H. Amundsen and Fridulv Sagberg have carried out the literature survey and have written the report. Fridulv Sagberg has been the project manager.

Marika Kolbenstvedt has been responsible for quality assurance, and Trude Rømming has prepared the report layout for printing and publishing.

Oslo, May 2003
Institute of Transport Economics

Knut Østmoe
Managing Director

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Head of Department

Table of contents

TØI report 659/2003
Authors: Astrid H. Amundsen and Fridulv Sagberg
Oslo 2003, 34 pages English language

Summary:

Hours of service regulations and the risk of fatigue- and sleep-related road accidents

A literature review

This report is a literature review about implications of hours of service regulations for traffic safety. The rationale for implementing such regulations is that prolonged driving and/or lack of rest and sleep before work-periods result in fatigue and sleepiness during driving, which in turn impair driving performance and increase accident risk. A further assumption is that regulating the hours of service results in less driving by fatigued or sleepy drivers. To evaluate these assumptions, research on the following issues is discussed in the report:

- Effects of time behind the wheel, time on duty, and rest periods on fatigue, sleepiness, and driving performance.
- Variations in accident risk with working or driving time and with circadian rhythms, and the role of fatigue and sleep in accident causation.
- Driver compliance with hours of service regulations.

The regulations

Both to reduce the risk of serious accidents and to improve working conditions, hours of service regulations are implemented in most countries. The regulations differ somewhat from country to country, but are mainly focused on three aspects:

- limitations regarding the maximum hours on duty during a 24-hour period
- requirement to take at least one rest break during the workday
- requirement for rest between the work-periods.

The regulations imply that the drivers and the company are responsible for documentation of service hours, either by the driver at roadside inspections or by the company for all its vehicles. Therefore, for enforcement purposes trucks are required to be equipped with a tachograph (or, in some cases it is sufficient that the driver keeps a log-book).

Fatigue, drowsiness and driving performance

Fatigue and falling asleep while driving is a well-known problem for the long-distance truck drivers. Research indicates that more than 50 percent of long-distance truck drivers may have fallen asleep at the wheel at least once in their

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career as a driver. One study reported that 51% of a random sample of drivers had experienced fatigue during their latest trip, and 35% reported this to be a problem for them. Performance impairment is frequently reported among those who experience fatigue. Nodding off, lane deviations and near miss incidents are frequent.

The following hours-of-service violations are strong predictors of self-reported drowsy driving: a) driving more than recorded in log book, b) taking less than 8 hours off, c) driving more than 10 consecutive hours, and d) a too tight delivery schedule.

Several studies have shown that sleep deprivation results in impaired driving performance. In addition, there are effects of the circadian rhythm that are independent on the amount of sleep. Performance is at its lowest during early morning hours, and there is also a dip in the early afternoon. Some researchers have compared sleep deprivation with alcohol impairment and have suggested that one night without sleep is equivalent to at least 0.05 % blood alcohol content. However, sleep deprived drivers are more aware of their impairment, and consequently more able to compensate as compared to those impaired by alcohol.

Time behind the wheel seems to have a relatively small effect on fatigue indicators, when control is made for sleep deprivation and time of day.

Accidents related to sleep and fatigue

Fatigue- and sleep-related accidents are on the average more severe than other accidents, due to being over-represented in high-speed driving conditions. According to the best estimates, fatigue or sleep is a contributing factor in about 15-20% of truck accidents. In official statistics the estimates are much lower, due to underreporting of driver fatigue or sleep in accident reports.

Drivers with sleep disturbances (sleep apnoea, insomnia, narcolepsy) have a two- to fourfold increase in the risk of crash involvement.

Even a small reduction in sleep (restricting sleep to less than 7 hours) has been shown to increase the accident risk by a factor of three. After sleep debt accumulated over several days, a minimum of 2-3 nights with normal sleep is required for complete recovery.

Effects of time behind the wheel on crash risk have been demonstrated only for very long continuous driving periods (9 hours or more), whereas the risk (just like performance and fatigue indicators) is more closely related to the circadian rhythm.

Young drivers are more prone to be involved in sleep-related crashes. And there seems to be a relatively small group of drivers with relative little sleep in general who are responsible for a disproportionately large share of the truck crashes.

Suggestions from truck drivers regarding measures to reduce the risk of fatigue- and sleep-related crashes include:

- More appropriate time schedules
- Teaching drivers how to recognize signs of fatigue, and how to manage it

- Better advance planning of journeys, in order to find suitable rest areas
- Improved efficiency in loading/unloading, to reduce waiting time
- Prohibiting drivers from doing the loading/unloading themselves
- Improved availability and quality of rest and parking areas
- Punishing both driver and company for breaking hours of service regulations.

On the background of the scientific evidence, both limiting the time of driving without rest, and securing sufficient rest between work periods seems to be appropriate measures to prevent fatigue- and sleep-related accidents.

Enforcement and compliance issues

On the basis of accident data it can be concluded that compliance with the existing rules will entail a lower crash risk compared to a system without regulations. In order to promote compliance a certain level of enforcement is necessary. According to a European Transport Safety Council report today's level of enforcement is not adequate, and the frequency of inspections differs greatly between different European countries.

Random inspections in Norway and Sweden indicate that more than one out of four drivers on the road is breaking one or more of the regulations for hours of service or correct use of the tachograph. Tampering with the tachograph or filling in data incorrectly on the tachograph disc appear to be a way of covering up other violations. The most common violation appears to be too short daily rest periods.

The level of compliance is obviously influenced by the frequency of inspections. In order to reduce the violation rate the European Council in 1988 introduced minimum requirements for monitoring compliance. A minimum of 1 percent of a driver's working hours must be checked out, either at the workplace or by roadside inspections.

A problem which may contribute to reduced compliance in international transport is that the level of sanctions and the interpretations of the EU regulations vary between the countries committed to those regulations.

Another possibly important aspect is to what extent the company vs. the driver is punished for violations. Punishing both the company and the driver probably results in higher compliance than punishing the driver only.

On the basis of the studies of compliance with the hours of service regulations it can be concluded that the proportion of violations is alarmingly high. To reduce the rate of violations, increased enforcement, lower tolerance of noncompliance, and harmonization of practice across countries is essential.

To improve the companies' consideration of fatigue and the hours of service regulations it is important that the sanctions are severe enough to deter the companies from accepting violations. More severe sanctions may lead to an increased focus on the problem, and development of educational programs and more formal fatigue management strategies. This may then also lead to improved

schedules, and that the companies to a higher degree may resist pressure from customers and dispatchers to accept unrealistic delivery conditions.

Conclusions

There is abundant documentation to support the efforts to regulate the length of both work and rest periods. The evidence is not clear as to what should be the optimal duration of work and rest periods, respectively, but it is obvious that the present regulations that exist in most countries, if enforced, may contribute to prevent the most extreme periods of work, which make up the highest risk.

The amount of rest *before* working has a strong effect on fatigue and performance during subsequent driving, and therefore it seems appropriate to recommend a stronger focus on this aspect.

The potential for hours of service regulations to increase traffic safety can possibly be enhanced by efforts directed at the following aspects:

- Enforcement and sanctions
- Limitations on night driving
- Improved technology for monitoring of compliance
- Company safety policies and factors related to work organisation and working conditions
- Better and more frequent facilities for resting during trips
- Information to drivers regarding the risks related to prolonged driving and inadequate rest.

Finally, if the regulations can allow more flexibility regarding the distribution of rest periods, without increasing the workload and/or reduce the amount of rest and sleep, it may contribute to improved working conditions for the drivers, and probably also to traffic safety.

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Sammandrag:

Betydelse av reglerna om kör- och vilotider för sömn- och trötthetsrelaterade trafikolyckor

En litteraturöversikt

Denna rapport redovisar en litteraturöversikt över betydelsen av reglerna om kör- och vilotider för trafiksäkerheten. Grundlaget för att implementera sådana regler är att oavbruten bilkörning över lång tid, och/eller brist på vila eller sömn innan man kör, kan förorsaka att föraren blir trött och även somnar bakom ratten, med ökad olycksrisk till följd. En vidare förutsättning är att reglering av kör- och vilotiderna leder till mindre körning bland trötta och sömniga förare. Dessa förutsättningar utvärderas i rapporten genom diskussion av forskningsresultat kring följande frågeställningar:

- Inverkan av tid bakom ratten, längd av arbetsperioder och viloperioder på trötthet, sömnighet och körförmåga.
- Variation i olycksrisk med arbetstid, körtid och dygnrytm, och betydelsen av trötthet och sömn som olycksorsaker.
- Förarnas överhållande av kör- och vilotidsreglerna, samt faktorer som påverkar detta.

Regelverket

Både för att reducera risken för allvarliga olyckor och förbättra arbetsvillkoren inom transportbranschen har regler för kör- och vilotider införts i de flesta länder. Reglerna varierar något från land till land, men är i huvudsak fokuserade på följande aspekter:

- Begränsning av den maximala körtiden under en 24-timmars period
- Krav på arbetspassens varighet och raster mellan passen
- Krav beträffande nödvändig längd på vila mellan arbetsdagar.

Föreskriften innebär at förarna och företaget är ansvariga för att dokumentera körtiderna, antingen vid redovisning från föraren vid inspektioner ute på vägen eller vid företagskontroller. För att kör- och vilotiderna skall kunna dokumenteras, måste tunga fordon vara försedda med färdskrivare. I några specificerade undantagsfall är det tillräckligt att föraren skriver upp tiderna i en loggbok.

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Trötthet, sömnighet och körförmåga

En möjlig och allvarlig följd av trötthet är att föraren tuppar till eller somnar under körningen. Trötthet och sömn under körning är ett välkänt problem bland förare av långtradare. Forskning har visat att mer än hälften av alla lastbilsförare har upplevt att somna vid ratten åtminstone en gång under sin karriär som förare. En studie visade att 51% av ett slumpmässigt urval av förare hade upplevt trötthet under den senaste turen, och 35% upplevde detta som ett problem för sig själv. Sämre körprestation rapporterades av många av dem som hade upplevt trötthet under körningen.

En undersökning visar att följande överträdelser av reglerna för kör- och vilotider tycks predikera självrapporterad körning i trött författning: *a)* mer körning än vad föraren officiellt rapporterat, *b)* mindre än 8 timmars dygnvila, *c)* mer än 10 timmars oavbruten körning, och *d)* för knappa tidsfrister på leveranserna.

Flera studier har visat otillräcklig körförmåga som följd av för lite sömn. Dessutom inverkar dygnrytmen på körprestationen oberoende av brist på sömn. Många färdigheter är sämst tidigt om morgonen, och det är också en mindre reduktion om eftermiddagen. Några forskare har jämfört sömnbrist med alkoholpåverkan och har uppskattat att en natt utan sömn tillsvarar 0,05% alkohol i blodet. Dock är sömniga förare mera medvetna om sin försämring, och de har därför bättre möjlighet att kompensera jämfört med alkoholpåverkade förare.

Tid bakom ratten tycks ha en relativt svag inverkan på trötthetssymptomen , när det kontrolleras för sömnbrist och tid på dygnet.

Olyckor relaterade till sömn och trötthet

Sömn- och trötthetsrelaterade olyckor är i genomsnitt mer allvarliga än övriga olyckor, därför att de oftare förekommer under höga hastigheter. Enligt de bästa tillgängliga uppskattningar bidrar trötthet eller sömn till ungefär 15-20 % av alla olyckor med tunga lastbilar. I den officiella statistiken är siffrorna mycket lägre, på grund av underrapportering av dessa medverkande faktorer i polisrapporter.

Förare med sömnstörningar (sömnapnésyndrom, sömnlöshet, narkolepsi) har två till fyra gånger högre risk jämfört med en genomsnittförare.

Även en liten brist på sömn (begränsning av sömnperioden till under 7 timmar) har visat sig att öka olycksrisken med en faktor på tre. Efter en akkumulerad sömnbrist över flera dagar, behöver en förare åtminstone 2-3 nätter med normal sömn för at kunna återhämta sig.

Effekter av tid bakom ratten på olycksrisker har demonstrerats bara för mycket långa körperioder (9 timmar eller mer), medan dygnrytmen tycks ha en större effekt på risken (på samma sätt som för indikatorer på sömn och trötthet).

Unga förare är mer olycksdrabbade än medelålders förare. Dessutom är en förhållandevis stor andel av lastbilolyckorna förorsakade av en liten grupp förare som har för vana att sova lite.

Förslag från lastbilsförare beträffande åtgärder för att reducera risken för sömn- och trötthetsrelaterade olyckor omfattar följande:

- Bättre planering av tidsscheman

- Lära förare att bättre uppmärksamma tecken på trötthet, och hur de kan hantera trötthetten på et mer effektivt sätt
- Bättre planering av turer i förvägen, med avsikt att finna lämpliga rastplatser
- Effektivare på- och avlastning, för att reducera väntetiderna
- Förbjuda förarna att själva lasta på och ur bilen
- Förbättrad tillgänglighet och kvalité på rastplatser och parkeringsplatser
- Straffansvar för både förare och företag för brott på kör- och vilotidsföreskrifterna.

De vetenskapliga resultaten indikerar at både begränsning av körtiderna och krav beträffande längden av vilotiderna är väl funderade åtgärder för at minska risken för trafikolyckor till följd av sömn och trötthet.

Övervakning och efterlevnad av regelverket

En rimlig slutsats på bakgrund av olycksdata är att bättre efterlevnad av befintliga kör- och vilotidsregler leder till lägre olycksrisk jämfört med ett system utan sådana regler. För att få förare i större mån att efterleva reglerna är ökad övervakning en lämplig åtgärd. Enligt en rapport från European Transport Safety Council är övervakningsnivån inom Europa för låg, och frekvensen av inspektioner varierar för mycket mellan länderna.

Slumpmässiga inspektioner i Norge och Sverige visar att mer än en av fyra förare av tungt fordon bryter en eller flera av reglerna för kör- och vilotider, eller för korrekt användning av färdskrivaren. Fusk med färdskrivaren eller felaktigt utfyllande av upplysningar på skivorna tycks vara et sätt att dölja andra regelbrott. Den vanligaste överträdelsen är brott på regeln om dygnvila.

Efterlevnaden av reglerna har en uppenbar sammanhang med frekvensen av inspektioner. För att reducera förekomsten av överträdelser införde Europarådet 1988 krav beträffande mängd av kontroller. Åtminstone 1 procent av en förares körtid skall kontrolleras, antingen vid företagskontroller eller vid inspektioner längs vägen.

Et problem som troligen medverkar till låg efterlevnad av regler inom internationella transporter, är att straffen så väl som tolkningen av reglerna varierar mycket mellan de länderna där det gemensamma regelverket gäller.

En annan faktor är huruvida företaget respektive föraren straffas för regelbrott. Straff för både föraren och företaget ger sannolikt bättre efterlevnad än om bara föraren straffas.

På bakgrund av de befintliga studier beträffande efterlevnaden av bestämmelserna om kör- och vilotider kan man dra den slutsats at överträdelsesprocenten är så hög att det ger grund till bekymmer. För att reducera antalet överträdelser är det viktigt både med ökad övervakning, lägre toleransgräns för överträdelser, och harmonisering mellan länderna vad gäller tolkning av regelverket.

För att förbättra företagens hantering av trötthetsproblemet och kör- och vilotidsreglerna, så att brott mot reglerna inte accepteras, är det viktigt att straffen har tillräcklig avskräckande effekt. Hårdare straff kan leda till starkare fokusering av problemen inom företaget, och till utveckling av program och strategier för professionell hantering av trötthetsproblemen. Detta kan i sin tur leda till förbättrad planering, och till att företagen lättare motstår press från kunder eller speditörer för att acceptera orealistiska villkor för leveranser.

Slutsatser

Det föreligger omfattande dokumentation till stöd för reglerande av både arbetsperioder och viloperioder inom transport med tunga fordon. Det är inte tillräckligt avklarat exakt hur långa kör- och viloperioder, eller kombinationer av dessa, som är optimalt. Dock verkar det ganska uppenbart att det regelverk som fins i dag, om det efterleves, är tillräckligt för att eliminera de extrema fallen av långa arbetsperioder och/eller sömnbrister, som utgör den största olycksrisken.

Längden av vilan *före* arbetsperioden har en stark effekt på trötthet och körförmåga; det är därför god grund att rekommendera et speciellt fokus på denna del av regelverket.

Effekten av kör- och vilotidsreglerna på trafiksäkerheten kan förbättras genom starkare fokusering av följande åtgärder:

- Övervakning och bestraffning
- Begränsningar på nattkörning
- Förbättrad teknologi för registrering av regelefterlevnad
- Företagens säkerhetspolicy och andra förhållanden beträffande arbetsorganisation och arbetsmiljö
- Bättre och flera faciliteter för rast och vila längs vägarna
- Information till förare om riskerna vid oavbruten körning och brist på vila och sömn.

Slutligen, därsom regelverket kan tillåta större flexibilitet beträffande fördelning av vilopauserna, utan att arbetsbelastningen ökar och/eller mängden av sömn och vila reduceras, vill det med all sannolikhet bidraga till bättre arbetsförhållanden för förarna, och sannolikt också ökad trafiksäkerhet.

1 Introduction

1.1 Background

Lack of sleep and rest leads to fatigue and reduced alertness, which may influence work performance. Drivers and especially long-distance-truck-drivers are no exception. Being alert is essential for safe driving. Drivers who know they are fatigued or sleepy may to a certain degree be able to compensate for this, for example by being extra concentrated on the driving tasks and the driving environment. But there is a limit for how long a person can be able to fight the effects of sleepiness.

Reduced alertness is known to result in increased risk of accident involvement. Accidents involving trucks or buses often have more serious outcomes than other accidents, due to the weight difference compared to other vehicles and road users. In fatal accidents where trucks are involved, a minority of the fatalities are truck drivers or passengers. Haworth et al. (1989) found that only 22% of the fatalities in such accidents were truck occupants. For buses, an additional factor to be considered is the large number of passengers possibly affected by a crash.

Both to reduce the risk of serious accidents and to improve working conditions, hours of service regulations are implemented in most countries. The regulations differ somewhat from country to country, but are mainly focused on three aspects:

- limitations regarding the maximum hours on duty during a 24-hour period
- requirement to take at least one rest break during the workday
- requirement for rest between the work-periods.

This report is a literature review about implications of hours of service regulations for traffic safety. The rationale for implementing such regulations is that prolonged driving and/or lack of rest and sleep before work-periods result in fatigue and sleepiness during driving, which in turn impair driving performance and increase accident risk. A further assumption is that regulating the hours of service results in less driving by fatigued or sleepy drivers. To evaluate these assumptions, research on the following issues is discussed in the report:

- Effects of time behind the wheel, time on duty, and rest/sleep before working on fatigue, sleepiness, and driving performance.
- Variations in accident risk with time on duty and/or driving time, and with circadian rhythms, and the role of fatigue, drowsiness and actually falling asleep in accident causation.
- Driver compliance with hours of service regulations; causes and consequences of non-compliance.

Research literature has been collected from Norwegian and Swedish libraries, and from different international websites and search engines, including: Transport, TRIS, TRAX and ISI Web of Science.

1.2 Hours of service regulations

In the European Economic Area (EEA), the hours of service regulations are based on EEC regulation number 3820/85. These regulations are restricted to vehicles with a total weight of more than 3.5 tons (with some exceptions). The regulations in the AETR countries[1] are quite similar to EEC no. 3820/85.

According to the regulations a driver is allowed to drive 9 hours daily (with a possibility for two days of 10 hours) during a week. After a maximum of 4.5 hours of driving, a 45-minute rest period is required (alternatively, two or three breaks of at least 15 minutes, totalling at least 45 minutes). When starting driving again after completing the prescribed 45-minute rest, a new maximum of 4.5-hours driving applies, with the same requirement of at least 45 minutes rest. The start of a new 4.5-hour maximum period applies even when driving less than 4.5 hours before completing the previous 45-min rest requirement. During a 24-hour period a daily rest of minimum 11 consecutive hours is statutory; this can be reduced to 9 hours maximum 3 times during a week (if compensated within the next week). After a maximum of six daily driving periods (which means a maximum of 56 hours driving) a weekly rest period of at least 45 hours is required. Under some specified conditions this can be reduced to 36 or 24 consecutive hours, provided that the reduction is compensated within three weeks in conjunction with another rest period of at least 8 hours. The driving time during a two-week period must not exceed 90 hours. The regulations are complex and may be subjects to alternative interpretations; therefore, detailed interpretations and examples have been presented in various guidelines (Swedish National Road Administration, 1998; Norwegian Public Roads Administration, 2001).

In the USA the regulations (U. S. Federal Hours of Service) of the hours of driving are similar to the EEA regulations. 10 hours of driving, or 15 hours on duty are allowed. Maximum time on duty during a 7-day period is 60 hours (Balkin et al., 2000; US General Accounting Office, 2000; US Department of transport, 2000a).

Australia allows a maximum of 12 hours of driving and 14 hours of work (including driving) during a 24-hour period (Dawson et al., 2001). Further, a break of minimum 30 minutes is required after 5.5 hours of driving, and one can work for a maximum of 72 hours during any seven day period. The hours of service regulations vary somewhat between the different Australian territories.

The main difference between the regulations in Australia (and New Zealand) and in EEA seems to be that the Australian regulations focus more on total hours on duty than the European regulations do.

[1] European agreement on road transport. AETR includes mainly Eastern European countries in addition to the EEA countries.

1.3 Tachograph

According to EEC regulation nr. 3821/85 all vehicles for which the hours of service regulations apply, must be equipped with tachographs (Norwegian Public Roads Administration, 2001). (Buses in regular service are exempted from this requirement.) If the tachograph is out of function for a period, the driver is required to keep a log-book while waiting for the tachograph to be repaired. On the road the driver is required to always be able to document the last week of driving, if asked for this at a roadside control.

The companies are required to save all the tachograph discs and/or logs for at least a year, and make them available in a potential control.

2 Fatigue, drowsiness and driving performance

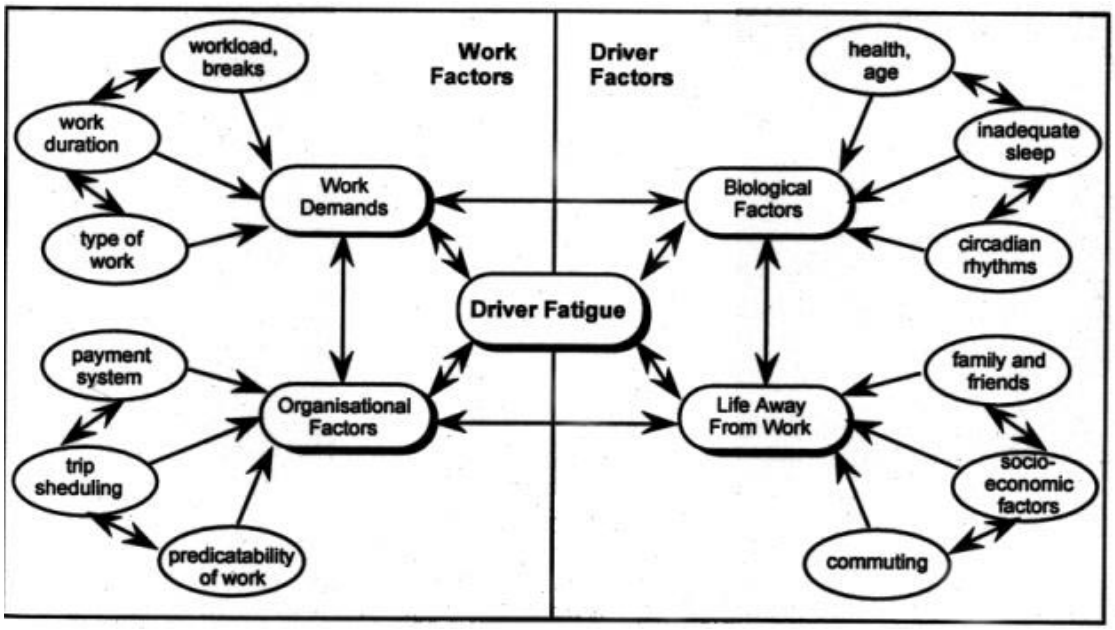

Figure 2.1: Factors contributing to driver fatigue. Source: Dawson et al. (2001).

2.1 Sleepiness vs. fatigue – different states of consciousness

A basic assumption underlying the use of hours of service regulations for the purpose of increased safety is that safety-critical driving performance is systematically related both to time on duty and to the length of rest before working.

The concept of 'fatigue' is widely used to describe the condition underlying the assumed performance decrement during prolonged driving. However, as several researchers have pointed out, fatigue is a vaguely defined concept (see e.g. Brown, 1993; 1994), and there seems to be several partly independent aspects of fatigue, as the concept is used in everyday language. Further, driver fatigue is considered to be the result of a complex interplay between different factors related both to the driver and to the working situation, as shown in figure 2.1 (Dawson et al., 2001).

For the present discussion of hours of service regulations and their possible effects, it is not considered necessary to delve very deeply into details regarding the various definitions and components of fatigue, but rather focus on the evidence of driving performance as related to rest periods and time on duty.

One possible and serious consequence of fatigue is drowsing or falling asleep while driving. It can, however, be questioned whether drowsiness (sleepiness, tiredness) and falling asleep while driving should be considered on its own, as a phenomenon separate from fatigue. It has been pointed out (Näätänen og Summala, 1978) that falling asleep may occur without necessarily being fatigued.

Maybe the converse is also possible, namely being fatigued without being sleepy?

In that case it may be meaningful to consider these two states of consciousness separately, both regarding causes and consequences. Fatigue can be seen as a result of intense or prolonged activity, whereas drowsiness is the result of lack of sleep (and/or of monotony and lack of stimulation). Concerning remediation they are also different, fatigue is alleviated by rest, and drowsiness by sleep. Both states can conceivably affect driving performance, but possibly in different ways. Fatigue may result in poor performance, whereas extreme drowsiness in addition results in non-performance. See also Johns (2000) for a discussion of the distinction between drowsiness, sleepiness and fatigue.

Obviously the two phenomena are closely correlated, but it may be useful to consider them separately in the discussion of traffic safety aspects. In the following presentation we will therefore try to consider sleep, drowsiness and sleep-related states of consciousness (collectively termed *sleepiness* here) as separate from *fatigue* and related states.

2.2 Sleepiness while driving may have different causes

Brown (1993) points to the following factors that may influence the risk of falling asleep while driving:

- Lack of sleep or poor quality of sleep
- Circadian rhythm
- Long working hours
- Individual characteristics, including medical conditions
    - Age, fitness, biological clock (morning-active vs. evening-active persons), driving experience, sleep disorders
- Lack of stimulation, monotonous environment.

It should therefore be emphasised that the regulation of working and resting hours is only one of several means to combat driver fatigue. Another important consideration is that there may be interactions between the various factors. For example, the combination of many hours at the wheel and a monotonous driving environment may have a stronger effect than the sum of the separate effects of the two factors.

2.3 Other related states of consciousness – drivers' awareness of sleepiness

Actual sleep is sometimes preceded by brief periods of so-called *microsleep,* which means just dozing off for a few seconds. This seems to occur especially when one tries to stay awake despite being very sleepy. According to Taoka (1998) the driver's awareness of these microsleep episodes depends on their duration. Ordinarily, drivers are aware of microsleep shorter than about 2 seconds. If the duration is 2 – 6 seconds, the driver may not be aware that consciousness was lost for a moment. As the duration exceeds 6 seconds, reawakening the driver becomes increasingly difficult, and his state turns into actually falling asleep. Thus, according to Taoka (1998) the time it takes to fall asleep lasts somewhere from about 6 seconds to about 24 seconds.

Experimental studies of microsleep indicated by measurement of eye-closure have been reported by Summala et al. (1999) and Häkkänen et al. (1999) at the University of Helsinki. In the former study, drivers drove 1200 km in an instrumented car during the night. The drivers stated the following subjective effects of drowsiness or fatigue: Increased eye-blinking frequency and duration, microsleep, numb muscles, sore eyes, hard to focus, hallucination, hard talking, apathy, reduced attention, incoherent memory and stomach ache. The second study comprised bus drivers with obstructive sleep apnoea syndrome, who were tested before and after treatment with "continuous positive airway pressure" (CPAP). Eye-closure was shown to be a useful indicator of sleepiness and microsleep in both studies.

The question of driver awareness of the early signs of falling asleep is interesting from the point of view of drivers' possibilities of taking action when certain symptoms occur. Reyner and Horne (1998) concluded on the basis of a simulator study that falling asleep was always preceded by a period of sleepiness, of which the drivers were aware, but some drivers did not appreciate the increased risk of actually falling asleep implied by the sleepiness symptoms. They therefore suggested that "there is a need to educate at least some drivers that extreme sleepiness is very likely to lead to falling asleep and a high accident risk".

It has been suggested that some states of consciousness may gradually lead to sleep without the driver's awareness. The so-called state of "highway hypnosis" seems to be a result of prolonged driving in monotonous environments, and may occur in rested drivers even in the middle of the day. Williams and Shor (1970) defined highway hypnosis as "a tendency to become drowsy and to fall asleep when driving an automobile". It has been pointed out that this sleep-like or trance-like state can occur with the driver sitting in an upright position an staring ahead, and that it is often accompanied by "hallucinatory experiences and distortions of thought and judgement" (Williams, 1963). These experiences seem to be examples of so-called hypnagogic imagery (Schachter, 1976), which refers to the mental contents characterising the transition state from wakefulness to sleep. Wertheim (1991) has suggested that highway hypnosis is the result of the driving task becoming increasingly automatic due to a highly predictable road environment, with a reduced level of arousal as a consequence. A similar state has been described by Kerr (1991) as the driving without awareness mode (DWAM). This refers to the experience of having been driving for a long time without being

able to recall anything from the trip. The relationship of these phenomena to falling asleep, and the possibility of falling asleep without recognizing the symptoms in advance, should be further investigated (see also Näätänen and Summala 1978).

2.4 Working hours and sleepiness/fatigue

Fatigue is a well-known problem for the long distance truck drivers. Research indicates that more than 50 percent of long distance truck drivers have fallen asleep at the wheel at least once in their career as a driver (European Transport Safety Council 2001).

Sleepiness as indicated by subjective reports tends to increase with increasing driving distance (Storie 1984).

The effects of long-distance truck driving on fatigue, performance and safety has been extensively studied in Australia, particularly by Ann Williamson and her co-workers at the National Institute of Occupational Health and Safety in Sidney.

Williamson, Feyer and Friswell (1996) compared three different work practices concerning effects on various measures of fatigue after a 10-12 hour trip (900 km). The three conditions were:

0) relay (staged) driving - returning to home base on each trip (driving halfway, changing truck and returning)
0) flexible driving (take breaks at own discretion)
0) control (breaks according to regulations)

The tests of sleepiness and performance included “critical flicker fusion” (CFF), Stanford Sleepiness Scale, reaction time, and others. They found that none of the driving regimes prevented fatigue. The level of fatigue during the trip was rather related to pre-trip fatigue levels, indicating that the effect of accumulated fatigue over several days may overshadow the effects of fatigue on a single 10-12 hour trip. The authors point out the needs for regulations to allow adequate rest between trips and blocks of trips to reduce sleep debt and fatigue.

Williamson et al. (1992) found in a survey among long-distance truck drivers that as many as 51 percent of the drivers had experienced fatigue on their latest trip, and 35 percent reported fatigue to be a problem for them personally.

In a similar study of both truck and coach drivers (Feyer et al., 1993) 18 percent of the drivers reported fatigue during driving to be a substantial problem for them personally.

Williamson et al. (2001) found in a survey sample of 1007 long distance drivers that 76 percent considered fatigue to be a “substantial” or “major” problem in the industry, but only 21 percent felt that this also applied to them. Almost 50 percent of the drivers had experienced fatigue on their last trip. 71 percent of the respondents were aware that fatigue impaired their driving performance. Commonly reported effects on driving performance were: slowed reactions, poor gear changes, driving to slowly and poor steering. It was also found that 45 percent of the drivers reported to have been fatigued during their latest trip, and

almost half of these (21%) reported at least one incident related to fatigue or drowsiness during the trip (e.g., nodding off, lane deviation, near miss incidents).

A tendency to think that fatigue to a higher degree is a problem for other drivers was also found by Arnold et al. (1997). In this study of 839 truck drivers, 10 percent reported that fatigued "always" or "often" was a problem for them, while 39 percent felt that this "always" or "often" was a problem for other drivers.

In Belgrade, Milosevic (1997) found changes in several subjective and physiological indicators of fatigue, as well as in visual reaction time, when he compared the reactions of bus drivers before and after 7 hours of city driving.

In an interview study including 593 truck drivers in the state of New York, McCartt (1999) found that the strongest predictors of the frequency of drowsy driving were:

- Driving more than recorded in the log book
- Taking less than 8 hours off duty
- Driving more than 10 consecutive hours
- Having an unrealistic delivery schedule.

The correlations between these factors and self-reported drowsy driving ranged from 0.24 to 0.30.

2.5 Circadian rhythms

Several bodily processes show systematic diurnal variations that may affect the performance of various tasks. These variations are referred to as *circadian rhythms* (from Latin *circa diem:* about a day). It is difficult to disentangle the behavioural effects of the circadian rhythm from those of working hours or sleep loss. It has been demonstrated that subjective drowsiness symptoms are most common during early morning hours (Williamson et al. 2001). However, the circadian rhythm is intertwined with the sleep schedule, in so far as the early morning dip is concerned. Driving early in the morning at the time one ordinarily is asleep necessarily imply loss, either due to staying up during the night or waking up earlier than normally. The circadian rhythm also has a variation during the day, which is not confounded with sleeping pattern in the same way. If performance changes with the biological rhythm during the day, it cannot be explained by sleep deprivation, since the level of activation falls during the afternoon and increases again in the evening (Nairn, 1987).

2.6 Working hours and driving performance

A study by Balkin et al. (2000) demonstrated very clearly the effects of sleep deprivation on performance Limiting time in bed to 3, 5 or 7 hours per night for one week all resulted in reduced performance. For the most severe sleep deprivation (3 hours in bed), three nights with normal sleep afterwards turned out to be insufficient for the performance level to recover to normal. They found some

day-time performance impairment even with the smallest reduction in sleep (7 hours).

Increasing time without sleep affects reaction time and vigilance tasks more than other functions. Professional drivers, however, show less performance decrement with sleep loss than other drivers. Williamson et al. (2000a) conclude that driving more than 16 hours without sleep is clearly hazardous, whereas Williamson et al. (2000b) found workdays of 14 hours relatively unproblematic for the drivers, even if part of the driving took place at night, provided that a sufficient rest period preceded the shift (all drivers in this study had been off duty for at least 24 hours).

Truck drivers' self-reports indicate that fatigue influences their driving performance, resulting in increasing reaction time, gear shift errors and reduced speed (Williamson et al. 2001).

Ranney et al. (1999) found that exposure to glare resulted in reduced hazard perception and critical tracking performance during 8 hours of driving in a simulator. This indicate that night driving may contribute to impairment due to the glare from the headlights of other vehicles, both from oncoming vehicles and glare reflected by the rear mirror.

A couple of studies have compared effects of prolonged wakefulness on performance to the effects of alcohol impairment. Fairclough and Graham (1999) found that the effect of one night sleep deprivation on driving performance was similar to that of 0.07 % blood alcohol content (BAC). An interesting finding was that drivers were more aware of impairment caused by sleep loss than by alcohol, and consequently better able to compensate.

Arnedt et al. (2001) also compared sleep deprivation with alcohol impairment regarding effects on driving behaviour. They found 18.5 hours without sleep to be equivalent to 0.05 %, and 21 hours equivalent to 0.08 % BAC.

Freund and Vespa (1997) compared different schedules in respect of various performance and fatigue indicators (psychophysiological measures, reaction time etc.) in an operational real-life setting. The found that the number of hours of driving was not a strong or consistent predictor of observed fatigue. The strongest factor influencing driver fatigue and alertness tended to be the time of day.

3 Sleep- and fatigue-related accidents among long-distance truck-drivers

3.1 Sleep and fatigue as contributing factors to accidents

Fatigue and sleep are especially common contributing factors in single-vehicle-accidents, but also some head-on-accidents (Dawson et al., 2001; Horne et al., 2001; Åkerstedt & Kecklund, 2000; Sagberg 1999; McCartt et al., 1998b; Hartley 1995; Summala & Mikkola, 1994). According to Sagberg (1999) fatigue is over-represented in accidents during nighttime, single-vehicle-accidents, driving more than 150 kilometres and injury accidents. Horne et al. (2002) also stated that due to high speed at the time of the accident fatigue/sleep related accidents often have more serious outcomes.

According to recent literature reviews fatigue seems to be a contributing factor in 15-20 percent of the truck accidents (see table 3.1). Some studies indicate that fatigue is involved in as much as 60 percent of the accidents, while one official national statistics indicate that fatigue account for just 0.5 percent of the accidents (see table 3.1). Fatigue as a contributing factor to accidents is assumed to be highly underreported in the official statistics (European Transport Safety Council 2001).

3.1.1 The role of sleep and fatigue may be difficult to verify

One of the main problems when evaluating accident data is that it may be hard to determine whether fatigue was involved or not. Unlike e.g. blood alcohol level the degree of fatigue is difficult to measure. Police and forensic experts are therefore dependent on interviews with the driver or witnesses to the accidents, or on their own experience with handling these kinds of accidents.

Accidents where falling asleep at the wheel was an obvious reason (high speed, no sign of braking etc), may therefore in some cases be the only type of fatigue related accidents registered in the official statistics. In some countries fatigue is not even an alternative cause or contributing factor on the forms filled out after an accident (European Transport Safety Council 2001).

How to improve the representativeness of the official statistics concerning fatigue as the main cause of the accident, or as a contributing factor is an important question. There is a need of an international standardisation of sleep- and fatigue-related accidents, and how to separate these types of accidents. To do this a set of criteria have to be set, or a way to measure the degree of fatigue or sleepiness has to be found.

Table 3.1. Summary of research on sleep- and fatigue-related accidents. Estimated proportions of accidents where sleep or fatigue is considered to be either the main or a contributing factor.

Type of study and main results	Type of vehicle	Reference
In depth and survey studies		
30% of single vehicle accidents seem to have been caused by the driver falling asleep.	Trucks	US DOT, 1970
3% of the drivers involved admitted to feeling fatigued. Police reports indicated that 5% of the drivers had fallen asleep at the wheel. ("On the spot investigation" of 943 accidents)	Trucks	Storie, 1984
Fatigue main reason in 41% of all accidents, another 18% has fatigue as a contributing factor.	Trucks	Transp. Res. and Marketing, 1985
Fatigue contributing factor in 9.1% of the accidents, according to experts on forensic medicine. (186 fatal accidents)	Trucks	Haworth et al., 1989
31% of the accident presumed to be caused by fatigue. (182 fatal accidents)	Trucks	US NTSB, 1990
4% of truck accidents and 10% of car/van accidents related to sleep or fatigue. (1943 fatal accidents)	Trucks and cars	Summala & Mikkola, 1994
2% presumed to be caused by drivers falling asleep at the wheel, or by fatigue. (From accident database –2758 accidents)	Trucks	McCartt et al., 1998b
4% of the accidents seem to be the result of drowsiness or falling asleep. (Insurance records –3239 accidents)	Cars	Sagberg, 1999
Between 16 and 30% of the accidents on 3 different road sections were possible/probable sleep related accidents. (820 personal injury accidents)	All types	UK DOT, 2002
Self reported accidents, interview with driver		
Fatigue contributing factor to 12% of the accidents. (839 drivers[2])	Trucks	Arnold et al., 1997
7% of the accidents partly due to drowsiness/fatigue. (593 drivers[3])	Trucks	McCartt et al., 1998a
11% of the drivers reported that they at least once in their career had been involved in an accident caused by fatigue/drowsiness. (317 drivers)	Trucks	Häkkänen & Summala., 2000
Fatigue contributing factor in 20% of the accidents. (1007 drivers[4])	Trucks	Williamson et al., 2001
Literature review		
In depth studies of accidents indicate that fatigue is a contributing factor in 10-25% of the accidents. In the official statistics fatigue is just a contributing factor in 0.5-0.7% of the cases.	Trucks and cars	Maycock, 1995
Driver fatigue a significant factor in approximately 20% of the accidents, and in about 3% of accidents in the official statistics.	Trucks	European Transport Safety Council, 2001
Loss of sleep and drowsiness, the cause of 15-20% of all accidents on monotonous roads (specially on motorways)	All types	Horne et al., 2002

Source: TØI Report 659/2003

[2] 9% reported to have been involved in an accident during the last 9 months.

[3] 22% reported to have been involved in an accident during the last 5 year period.

[4] 12% reported to have been involved in an accident during the last 12 months.

3.1.2 Criteria for fatigue or sleep involvement

Some criteria for separating sleep- and fatigue-related accidents from other kinds of accidents have been tried out in different studies. Haworth et al. (1989), estimated sleep or fatigue to be involved in about 20 percent of the accidents in their study. This estimate was based on the following criteria in the absence of verified fatigue or sleep involvement:

- Extended driving hours
- Evidence of falling asleep at the wheel
- Comments about tiredness prior to the accident
- Driving right[5] of centre in the absent of elevated BAC
- Night time driving.

Horne et al. (2002) list the following criteria used to evaluate whether an accident is a ”possible” or ”probable” sleep-related-vehicle-accident (SRVA):

1. Good weather conditions and clear visibility
2. Breathanalyser or BAC level below the legal limit
3. No mechanical defects on the vehicle
4. Elimination of “speeding” and “driving to close to the vehicle in front”
5. Driver had no known medical disorder to cause accident
6. Vehicle either ran off the carriageway, or ran into another vehicle that was clearly visible for several seconds beforehand – i.e. the incident was easily avoidable, implying prolonged inattention
7. No signs of pre-impact emergency steering or braking, e.g. no skid marks before the impact
8. The police officer at the scene suspected “sleepiness”.

If all criteria 1 through 7 are satisfied, the accident is judged to be a “possible” SRVA; if criterion 8 is satisfied in addition, the conclusion is a “probable” SRVA.

The criteria used in Horne et al. (2002) seem to intercept the main characteristics of fatigue and its effect on performance. Combining these criteria with possible interviews with witnesses, and information from the tachograph or logbook can give further information on what caused the accident.

[5] Left-side driving (Australian study).

3.2 Factors influencing sleep-related accidents

3.2.1 Sleep and sleep deficit

Getting adequate rest and sleep is essential to avoid getting drowsy or fatigued during work. Both the time of sleep during a 24-hour period and the quality of that sleep is important, as well as sleep during the last week. An adult person normally needs 7-8 hours of sleep per night.

The quality of the sleep is better if the sleep takes place during late afternoon and night; this is due to the circadian rhythm (see Section 2.5). Sleeping during daytime, too little rest, sleep fragmentation, and using the truck's sleeping berth are factors that can influence the quality of the sleep. Personal factors like stress, sleep disorders, and other aspects of health can also reduce the sleep quality.

Hertz (1988) studied the effect of fragmented sleep patterns (2*4 hours) for US truck drivers using the truck's sleeping berth. Drivers having fragmented sleeping patterns had 3 times the risk of being involved in a fatal accident compared to drivers with one uninterrupted sleeping period.

According to Åkerstedt and Kecklund (2000) sleep apnoea (sleep disturbances and fragmentation due to impaired breathing), insomnia, and narcolepsy increase the risk of fatigue-related accidents by a factor of 2 to 4.

Being under the influence of alcohol can increase drowsiness. Too much alcohol can also lead to sleep disturbances, meaning that 8 consecutive hours of sleep may not be enough to get adequate rest (Åkerstedt and Kecklund, 2000).

In a study of 50 truck drivers during a 20-day period, no adequate off-duty time was found that guaranteed all the drivers enough sleep (Balkin et al., 2000). This was due to differences in sleeping patterns between the drivers.

To get enough sleep, it is essential to have enough time off duty; 8 hours off duty is not enough to get adequate sleep during a 24-hour period. Drivers like other people need time to eat, exercise, rest/relax, spend time with family/friends as well as time to sleep. Research (US Department of Transportation, 2000b) indicates that 10-16 hours of duty is needed between each work shift.

With 6 to 7 hours of sleep the risk of accidents or dangerous incidents is about 3-times higher than with normal sleep (Hartley et al. 1996, Stutts et al. 1999).

Sleeping as little as 6 hours per night for a longer period will give a cumulative "sleep debt" which may be hard to recover from. Different studies indicate that drivers need at least 2-3 nights sleep to recover from cumulative "sleep debt" (Balkin et al., 2000: Dawson et al., 2001). It is therefore essential that drivers get enough off-duty time both for sleeping and resting after a period of sleep deficit.

3.2.2 Duration of a work-day

According to a number of studies, there is no clear correlation between driving hours and the rate of accidents (Ouwerkerk, 1987; Åkerstedt & Kecklund, 2000), European Transport Safety Council 2001). This may be due to the fact that working time alone is not the only factor influencing performance as a driver.

Naturally it makes a difference to the driver's alertness to start driving at 8 a.m. after having had 8 hours of quality sleep in his own bed, compared to starting at 5 p.m. after staying awake for 10 hours. Some work tasks and types of driving are more demanding than others, and this can make the driver fatigued earlier than usual (Dawson et al., 2001). In this connection it is important to evaluate both the driving time and the total time on duty. Time on duty may include loading/ unloading of the vehicle, which can be very tiresome. When determining the risk related to a long workday it is therefore important to know the driver's state of fatigue when he starts driving.

Studies indicate that fatigue can appear right after the start of the journey (European Transport Safety Council, 2001), but that there is a tendency for an increased risk when driving more than 9-11 hours (Hamelin 1987; Elvik et al., 1997; European Transport Safety Council, 2001). Elvik et al. (1997) indicate that driving more than 9 hours can increase the risk of accidents by about 3 times.

In the US Department of Transportation report (2000b) on proposed hours of service rules it was stated that "*approximately 20 percent of the fatal crashes per year where fatigue is coded as a factor, involve the driver being behind the wheel for 13 hours or more*".

Breaks with time for rest and eating is also important to reduce the effects of long working hours.

3.2.3 Time of day

Night-time driving is an obvious cause of fatigue-related accidents. This is due to the fact that this is the time of the day when the activation level related to the circadian rhythm is at its lowest, as well as to insufficient quality sleep during night-time (Åkerstedt and Kecklund 2000).

Dawson et al. (2000) identified 3 different factors influencing night-time crash risk:

- Higher risk of crashes due to environmental conditions (i.e. reduced visibility in darkness)
- A lower level of alertness and higher risk of crashes because of circadian rhythm effects
- A higher risk of crashes because of the reduced opportunity for restorative sleep.

The risk is highest when driving at night, having had a long workday, or having an irregular work-schedule. Between midnight and 6 a.m is a period with high risk of accidents, with the period between 2 and 5 as the peak. The maximum risk period during nighttime can be as much as 10 times higher than the risk during day-time (European Transport Safety Council, 2001; Freund and Vespa, 1997). In addition, night-time driving usually involves some extent of sleep deprivation due to an extended waking period.

About 50 percent of all sleep-related accidents happen between midnight and 9 a.m. (se figure 3.1), at a time when the traffic volume is low (Horne and Reyner, 1995). In a study by Milosevic (1997) it is reported that about 70 percent of the

single-vehicle accidents happen between midnight and 8 a.m., despite the low traffic volume during this period.

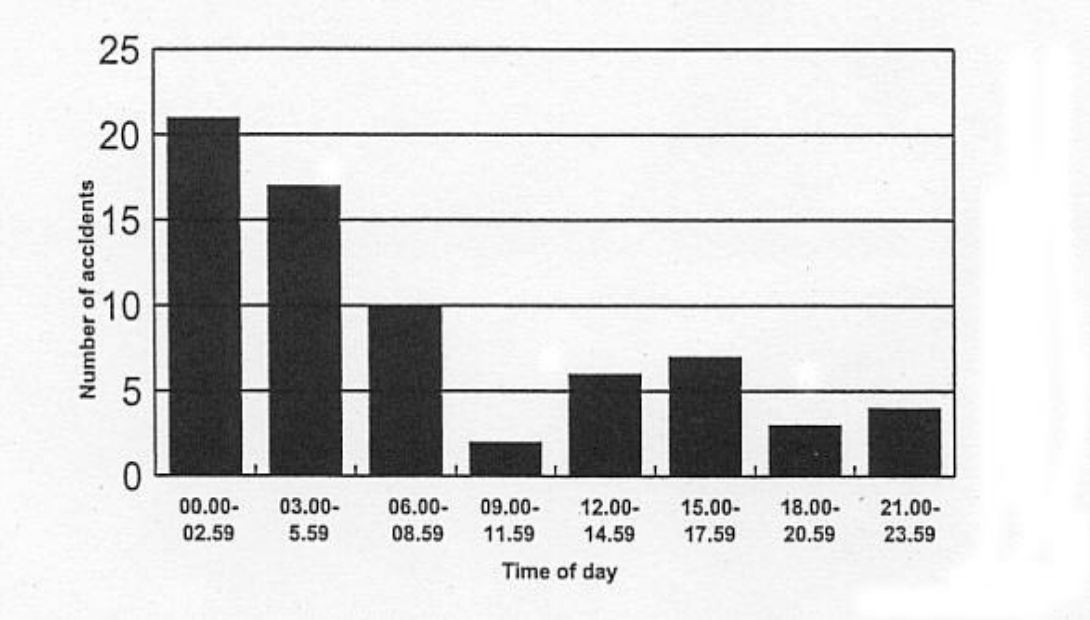

Figure 3.1: *Sleep-related accidents and time of day.* Source: Horne and Rayner, 1995.

3.2.4 Personal factors

Professional drivers seem to a higher degree to be able to control/compensate for the loss of sleep while driving, and they have a somewhat lower risk of accidents than other drivers (Hamlin, 1987; Brown, 1993; Summala, 1994; Williamson, 2000b). This may be due to their knowledge and experience of fatigue, and how to handle it. Many professional drivers learn how to recognize the early signs of fatigue, and how to take appropriate action (e.g., stop to take a nap and/or some coffee).

There is a tendency for younger drivers to have a peak in fatigue-related accidents from midnight to 6 a.m. and for older drivers to have a peak in the early afternoon (Summala and Mikkola, 1994; Horne et al., 2002). Horne et al. (2002) also indicate that younger drivers have a somewhat higher risk of being involved in fatigue-related accidents than older drivers, this may be due to younger drivers' higher accident involvement in general.

People have different needs for sleep, and have different sleeping patterns. Some people prefer to go to bed early, and others can't get any sleep until after midnight. To reduce the risk of being involved in an accident it is therefore, if possible, important to take one's individual biological rhythm into consideration when deciding when to drive.

The accident risk tends to differ between drivers, so that a relatively small number of drivers are responsible for causing the majority of the accidents (Ulleberg, 2002). Hanowski et al. (2003) reported that 20 percent of the short-distance truck-drivers were involved in 60 percent of the recorded near-miss incidents. The same tendency might also apply to long-distance drivers.

Some drivers are more affected by fatigue than other drivers (e.g., those who suffer from sleeping disorders), and some do not take the problem seriously enough (e.g., take alcohol or drugs, or don't take care to get enough sleep). In a study by Arnold et al. (1997) 20 percent of the truck drivers reported that they had slept less than 6 hours before their present trip; they accounted for 40 percent of the near misses/dangerous incidents. Finding methods to influence the behaviour of this group of drivers, or to select them out of the professional driving business could improve safety considerably.

According to US NTAB (1990) 33 percent of truck drivers killed in accidents tested positive for use of different kinds of substances, including alcohol, marijuana, cocaine, amphetamines, opiates or phencyclidine (PCP). There seemed to be a strong relationship between drug use and breaking the hours of service regulations.

3.2.5 Traffic environment

Monotony is one of the factors mentioned by drivers when describing factors having a adverse effect on fatigue (Feyer et al., 1993). Motorways and especially rural motorways are considered to increase the risk of related incidents/accidents (Maycock, 1995; Åkerstedt and Kecklund, 1999; Horne et al., 2002).

This may be due to the lack of stimuli when driving on motorways, especially when the traffic is low. Driving in traffic environment with little traffic can reduce the driver's attention on the driving tasks compared to the degree of concentration he would normally have in a more complex environment (cfr. also Section 2.3). Landscapes and traffic environments with little variation can also add to the feeling of boredom. According to Dawson et al. (2001) drivers get fatigued when having monotonous work.

3.2.6 Combinations of factors

Driving performance is dependent on: length of the last sleep period, time since last sleep period, the quality of the sleep, and the sleep history during the last week (Balkin et al., 2000).

The time of day and the driver's sleep- and rest history seems to have the highest correlation with accident rate. These factors are more important when it comes to influencing fatigue and drowsiness, than the time on duty or at the wheel during that particular day.

3.3 Countermeasures against fatigue- and sleep-related accidents

In an interview study with 593 truck drivers in New York (McCartt et al., 1998a) the following factors were mentioned most frequently as causing fatigue or drowsiness:

- Tight schedules
- Irregular working and resting periods

- Schedules involving night and late evening work
- Long workweeks (including loading/unloading, and waiting)
- To short continuous sleeping periods
- An increased part of the sleep during day time
- Breaking the hours of service regulations.

Long-distance truck drivers are aware of fatigue as a problem in the industry and its consequences for driving performance. Experience and education can learn them to recognize the early signs of fatigue, and when to take precautions. Which countermeasures that are most effective depends to a certain degree on the driver.

Commonly used countermeasures among truck drivers, are (Williamson et al., 2001):

- Sleeping
- Caffeine drink
- Taking a rest
- Listening to music/radio
- Ventilation/cold air
- Taking a shower
- Taking a short walk.

Sleeping is by far the most commonly used (and obviously the most effective!) way to manage sleepiness, together with drinking caffeine, resting and listening to music. According to Horne et al. (2002) the combination of caffeine (150 mg) and a short nap (15 minutes or less) is an effective way to get restored from drowsiness.

Taking staying-awake drugs is a decreasing way to handle fatigue, but it is still used by some. In an Australian study (Williamson et al., 2001), about 20 percent of the drivers stated that they at least occasionally used staying-awake drugs to reduce fatigue. Both non-prescriptive (legal) and illegal types of drugs are used. In 1990 about 37 percent of the respondents (820 truck drivers) used drugs occasionally, while 9 percent used it on every trip (Hensher et al., 1991).

When drivers were asked which operational countermeasures would be most helpful in reducing fatigue (Williamson et al., 2001; McCartt et al., 1997;1998a), the following answers were most frequent.

- Schedules that make it possible to reach the final destination without breaking speed limits or the hours of service regulations
- Education (learning how to recognize the signs of fatigue – their limits and how best to manage it).
- Handing out the schedules in time for the drivers to plan their journey up front. This can give them time to find suitable rest areas along the route.
- Improving efficiency in loading/unloading, to reduce time spent waiting.

- Prohibit drivers from doing the loading/unloading themselves.
- Improving the availability and quality of rest and parking areas.
- Punish both the driver and the company when the hours of service regulations are broken.

The quality and duration of sleep periods are important for safety. For the long distance truck drivers the quality, location and number of rest areas are therefore important. 80 percent of the drivers in an American study stated that commercial vehicle parking places "always" or "often" were full when they wanted to take a break for the night (McCartt et al., 1998a).

Drivers indicate that they prefer more flexible hours of service regulations (Feyer et al., 1993). A possibility to adjust the regulations to personal needs for sleep and rest periods (and when to take them) is wanted. As long as flexibility can be increased without increasing the total workload and/or reduce the total amount of rest and sleep, it would probably be a positive contribution towards better working conditions.

The question of whether the regulations are adequate in relation to the health and safety of the drivers can always be raised. Some authors have tried to set up certain principles based on the research evidence, to be followed when trying to optimise working hours to prevent drivers from falling asleep.

For example, Dawson et al. (2001) have presented the following guidelines:

- Get a minimum of 6 hours sleep per 24-hour period, preferably during the night
- After long periods with less than normal sleep, get two nights recovery sleep
- Avoid night driving as far as possible
- Work hours should not exceed 12-14 hours in one day, or 70 hours during a 7-day period
- Breaks should at lest comprise 10 % of the workday, and there should be a break of at least 15 min every 5 hours.

Except for the suggested limitation of night driving, these recommendations seem to accept slightly shorter breaks and longer driving hours than the current hours of service regulations. Until more firm research evidence can be provided, these guidelines should be considered as absolute minimum requirements for rest periods and maximum requirements concerning time of driving.

Concerning road infrastructure countermeasures, the use of rumble strips is considered very effective in reducing running-off-the-road accidents in general, including those related to fatigue or drowsiness (Gårder and Alexander, 1995; Chen et al., 2003).

4 Hours of service: Enforcement and compliance

4.1 Actual driving and working hours among truck drivers

Interviews with truck drivers indicate that hours of driving on average make up about 70-85 percent of the total time on duty (Baas et al., 2000; McCartt et al., 1997; 1999; Hamelin, 1999; Williamson et al., 2001). The rest of the time is spent on loading and unloading, waiting to be loaded/unloaded, and other tasks such as service on the vehicle and trip planning.

Table 4.1 gives an overview of driving and working hours among truck drivers in different countries. On duty times from 10 to 14 hours seem to be normal for truck drivers.

Table 4.1. Mean driving and working hours (day and week). International surveys.

Country	Hours of driving/hours on duty	Survey	References
Australia	38% exceed 14 hours of driving, 51% exceed 14 hours on duty (last 24 hours). *State with no regulations*	1249 truck drivers	Arnold et al., 1997
Australia	62.3 hours on duty in the last 7 days	40 truck drivers	Williamson et al., 2000a
Australia	20% have more than 72 hours on duty (last week)	1007 truck drivers	Williamson et al., 2001
New Zealand	9.72 hours of driving (last 24 hours) 11.89 hours on duty (typical workday)	600 truck drivers	Baas et al., 2000
US (New York State)	58.9 hours of driving during a 7 day period, 70.3 hours on duty during the same period.	593 truck drivers	McCartt et al., 1997 and 1999
France	7.67 hours driving and 11.2 hours on duty.	1006 HGV and 500 coaches.	Hamelin, 1999
Norway	10.1 hours on duty during a work day	3032 truck drivers	Ragnøy and Sagberg, 1999

Source: TØI Report 659/2003

Workdays as long as 10 to 14 hours give little room for other activities than eating and sleeping. Time to be with family/friends and to engage in other leisure activities is limited. Even with time off some weekends/weekdays, this kind of lifestyle may in the long term have an adverse effect on the driver's health.

4.2 Why regulate hours of service?

In an Australian survey from 1990 (Hensher et al.,1991) 22 percent of the drivers (820 truck drivers) reported that they had 140 hours on duty last week, while just 4 percent of the sample reported 60 hours or less on duty. If this is correct, 22 percent of the drivers had just 4 hours (mean) of sleep each day during that 7-day period.

The hours of service regulations are implemented to improve working conditions and safety in the transportation service industry. Regulations and frequent controls of compliance can reduce the amount of companies deliberately using long working hours as a way to compete with other companies.

As shown in the two previous chapters, long working hours and inadequate sleep lead to reduced alertness and performance, and increased crash risk. Regulating the hours on duty both on short and long term is therefore important to reduce the accident risk. Time for rest and continuous sleeping periods is of importance, so there is a need for regulating both the time on duty and the time of driving.

On the basis of the accident data presented in Chapter 3, it can be concluded that compliance with the existing rules will entail a lower crash risk compared to a system without regulations.

4.3 Surveillance and enforcement of compliance

Adequate enforcement is necessary to promote compliance with the regulations. If the involved personnel know that there is a high risk of being detected when breaking the rules, compliance will increase. According to European Transport Safety Council (2001) today's level of enforcement is not adequate, and the number of inspections differs greatly between different European countries.

During 2001, 60 179 trucks where controlled in Sweden (Rikspolisstyrelsen 2002). The official statistics from the police showed that 5 percent violated the hours of service regulations (EEC 3820/85), and a further 8 percent violated the use of tachograph regulations (EEC 3821/85). Of the 5 percent who had violated EEC 3820/85, 38 percent had violated the daily rest rule and 30 percent had violated the regulation regarding breaks during the trip (Rikspolisstyrelsen 2002).

In Norway, inspectors from the Public Roads Administration carry out random roadside checks on compliance with the hours of service regulations. For example, in 2002, 4700 vehicles were controlled. 7 percent of which had violated the daily rest rule (see table 4.2).

Table 4.2: Compliance with hours of service regulations in Norway. Source: Norwegian Public Roads Administration, 2003.

	1999 (%)	**2000 (%)**	**2001 (%)**	**2002 (%)**
Approved daily rest	91	93	92	93
Approved daily driving time	94	96	96	94
Correct use of tachograph discs	77	78	81	83
Approved tachograph	86	90	90	90

Source: TØI Report 659/2003

In another Norwegian study involving roadside inspections of 3032 trucks chosen randomly among trucks approaching the inspection sites, 25 percent of the drivers had violated one or more of the rules in the EEA regulations (Ragnøy and Sagberg, 1999). The daily rest-period was most frequently violated.

25 percent of the 1007 truck drivers in an Australian survey (Williamson et al., 2001) stated that they broke the hours of service regulations on every trip. In two Australian studies, 15 percent (250 truck and coach drivers) and 56.6 percent (960 truck drivers) of the drivers stated that the rules where broken on half or more of the trips (Feyer et al., 1993; Williamson et al., 1992). In McCartt (1998a) 20 percent of the 593 truck drivers interviewed in New York told that they "always" or "often" broke the hours of service regulations.

In 2002 the Swedish National Road Administration and the Police carried out inspections of a random sample of 113 national and international trucks on E6. Only 50 percent of the drivers complied with the regulations for both hours of service and for correct use of the tachographs. 12 percent of the drivers had violated the hours of service regulations, 21 percent had violated the tachograph regulations, while 26 percent had technical faults on their tachographs (Andersson 2003).

Andersson (2003) reports that in the official Swedish statistics on compliance, only 2 percent of the controlled drivers violate the regulations, but at the same time, as much as 80-90 percent of the drivers are reported to violate the rules in some of the more comprehensive type of controls. Incorrect use of the tachograph, failing to bring the required number of recorder discs, and technical faults with the tachograph are usual violations.

In 1988 the European Council introduced minimum requirements for monitoring compliance (European Transport Safety Council 2001). A minimum of 1 percent of a driver's working hours must be checked out, either in the company or by roadside inspections.

The number of inspections are reported to be too low, and the level of sanctions and interpretations of the regulations vary between countries committed to EEC regulation nr 3820/85 (European Transport Safety Council, 2001; Andersson and Serafimovski, 2001; Serafimovski and Widebäck, 1999). According to information from the Swedish National Road Administration, Sweden has a stricter interpretation of the regulations than Norway and Denmark. An example of a rather liberal practice in Norway concerns daily rest, where drivers don't get sanctioned unless they have less than 7 consecutive hours of daily rest (Justisdepartementet, 2000), although the regulations require a minimum 9 hours as an exception (ordinarily 11 hours). Different practice in different countries may cause confusion among the drivers and companies, and may lead to reduced respect for the regulations.

The level of penalty for violations is also likely to influence the degree of compliance. The fines differ considerably from country to country, and this is likely to result in different rates of compliance across countries. According to information from the Swedish National Road Administration, the normal fine for driving e.g. 6 hours without rest in Sweden is about 150 €, whereas the same

violation in Norway normally results in a fine of about 600-800 €. In some countries, the violations are even more strictly penalized, with fines for the mentioned violation in the order of 1000 – 1500 €, depending on the country.

For traffic violations in general, the relationship between penalties and compliance is, however, rather complex, and higher fines do not necessarily increase the compliance rate. Some studies of speeding have shown practically no effect on driving speeds after increasing the fines (Nilsson and Åberg, 1986; Andersson, 1989). The explanation is probably a low risk of being detected, and possibly also a lack of knowledge about the increased fines among drivers. These finding are probably applicable to some extent also to violations of hours of service regulations.

Thus, the effect of larger fines on compliance with hours of service regulations is likely to dependent both on the risk of being detected, as well as on the drivers appreciation of both the risk of inspections and the size of the fines.

Another possibly important aspect is to what extent the company vs. the driver is punished for violations. Punishing both the company and the driver probably results in higher compliance than punishing only the driver.

On the basis of the studies of compliance with the hours of service regulations and the use of tachograph regulations, it can be concluded that the proportion of violations is alarmingly high. This may partly be due to the fact that the risk of being detected is negligible and that the fines (at least in some countries) are too low to have any deterring effect. Another major cause might be that the regulations are complex, and that some drivers and companies don't have sufficient knowledge about the regulations.

To reduce the violations of the hour of service regulations, increased enforcement, lower tolerance of noncompliance, and harmonization of practice across countries are essential. Use of log-book or tachograph is necessary. In most countries this is already statutory. Inspections of both driving time and hours on duty is needed.

As in other businesses there is a strong competition in the transport industry. Both money and the ability to arrive on time are important factors in getting contracts. It is therefore essential that companies don't get a head start by breaking the rules, when competing with other companies. Enforcement is needed to follow up the compliance of the hours of service regulations. In the international long-haul transport industry there is also need for equal regulations in different countries. Today national variations on the hours of service regulation complicate an even competition (European Transport Safety Council 2001).

4.4 The industry perspective

Increased accident risk due to fatigue and drowsiness is a well-known problem in the transport industry, but there are indications that the issue is not taken seriously enough by the organisations and the companies; in many cases it seems to be up to the driver to find out how to handle the problem.

Drivers indicate that more education is needed, mainly concerning how to recognize the signs of fatigue and how best to manage it. Yet, just 20 percent of

the transport companies in a Western Australian study (Arnold and Hartley, 2001) had education programs in fatigue management strategies. Approximately 80 percent of the same companies reported that they did not have any formal fatigue management plan or policy for their drivers.

It may also be a problem that the majority of the drivers are paid by kilometres or by weight/volume of the freight. Some studies indicate that about 70 percent of the drivers are paid this way (McCartt et al., 1997; Williamson et al., 2001). Paying by kilometre or by weight may lead to an increased pressure on a driver to take a new trip before being fully recovered from the previous one.

To improve the companies' consideration of fatigue and the hours of service regulations it is important that the company is sanctioned when rules are broken. It is also important that the sanctions are severe enough to deter the companies from accepting violations, and actually include the fines as part of their budgeted costs. (It has been documented that some companies do so.) More severe sanctions may lead to an increased focus on the problem, and to development of educational programs and more formal fatigue management strategies. This may then also lead to improved schedules, and that the companies to a higher degree may resist pressure from customers or dispatchers to accept orders which are not possible to fulfil within the existing hours of service regulations.

If the company has a clearly expressed strategy not to accept violations, neither of hours of service regulations nor of speed limits, or the use of drugs, it may also be easier for the drivers to comply with this.

5 Discussion, conclusion and implications

The research evidence clearly shows that *time on duty* is related to fatigue and sleepiness, as well as an increased risk of actually falling asleep. Driving performance decrements are also shown to occur during prolonged driving. Furthermore, the risk of accidents increase.

All these effects are further influenced by the *amount and quality of sleep preceding the work period.*

It is also clearly shown that the circadian variations in the drivers' psychophysiological state results in variations in performance and crash risk, apart from those ascribable to length of rest and work periods.

The role of driving time versus total time on duty should be further investigated.

Certainly, more knowledge is needed regarding the circumstances and risk factors related to the time course of heavy vehicle accidents. Better criteria for determining the role of sleepiness vs. fatigue vs. actually falling asleep as contributing factors in accidents is needed. This implies better definitions of the various driver conditions involved, and the criteria should preferably be internationally standardised, to increase the comparability of accident statistics across countries.

Although the research results are fraught with caveats and cautions, there is abundant documentation to support the efforts to regulate the length of both working and resting periods. The evidence is not clear as to what should be the optimal duration of work and rest periods, respectively, but it is obvious that the present regulations that exist in most countries, if enforced, may contribute to prevent the most extreme periods of work, which make up the largest risk. Although the research results are somewhat inconclusive regarding the relationship between crash risk and driving times below 9-10 hours, there seems to be wide consensus that driving for longer than this amount is associated with increased crash risk, and thus the current regulations seem to be well founded.

A relatively clear finding from several studies is that the amount of rest *before* working has a strong effect on fatigue and performance during subsequent driving, and therefore it seems appropriate to recommend that this is focused in regulations and in information to drivers and employers.

There are two problems related to the enforcement of regulations, which may reduce their efficiency. One problem is that in some countries the responsible authorities have a rather high tolerance to violations. "Minor" violations don't result in any sanctions beyond an oral warning to the driver. For example, in Norway the instruction for enforcement of hours of service regulations accept daily rests periods as short as 7 hours before legal prosecution is initiated

(compared to 11 hours as stated in the regulations, with the possibility of reducing to 9 hours three times with subsequent compensation). Similarly, for the other regulations the tolerance levels are rather liberal.

The second problem, which is obviously related to the first, is the high rate of violations. The violation rate is probably a result of several factors in addition to the high tolerance on the part of the authorities. For one thing, it is rather easy to cheat with the tachograph discs. Furthermore, drivers have a pressure on efficiency, which is obviously a factor that motivates for violations. And the risk of apprehension is relatively low, so that it is possible to drive for rather long periods without being controlled. And the drivers have a well developed system for communicating information about controls to their colleagues, so that drivers who don't have clean hands may avoid being checked.

A problem related to the violations is the use of various stimulating drugs among drivers. Most of the documentation of this problem stems from the USA and Australia, whereas European data are more scarce. This should be investigated in Europe as well, to assess the prevalence of various kinds of drug use during driving. Is the problem increasing? To what extent are illegal drugs used, as opposed to over-the-counter drugs, and other stimulants like caffeine drinks etc? Even though drugs may keep drivers awake, some of them may have adverse effects on safety, and in the long term, addiction problems may ensue.

Although not clearly empirically demonstrated, it can at least be hypothesised that there is a relationship between the rate of violations and the accident risk, implying that drivers who often violate the regulations, are more frequently involved in crashes. There is a clear need for further research on this issue, for example in-depth analyses of accidents involving heavy vehicles, where the tachograph discs for the involved drivers are analysed, and compared to those of a random sample of drivers.

Assuming that such a relationship exists, measures to increase compliance with regulations would have a positive effect on traffic safety. Several possible measures to increase compliance, or in other ways increase the traffic safety of heavy vehicles, have been suggested in the research literature, both on the basis of the data on violations, sleepiness symptoms, driving performance, accidents and near-accidents, as well as on suggestions from drivers in interviews and questionnaires.

The countermeasures can be grouped into the following categories:

- *Enforcement and sanctions*

Both reduced tolerance levels before sanctions are imposed, and more frequent checks would contribute to higher compliance. Harmonisation between countries regarding interpretations of regulations, tolerance levels for sanctions, and magnitude of fines is also important. Different practices across borders may result in lowered compliance among drivers in international transport.

- *Limits on night driving*

Since the risk during the night is particularly high, apart from the effect of sleep debt, the possibility of imposing restrictions on night driving should be considered.

- *Improved technology for monitoring of compliance*

There are several possible improvements of the electronic systems for tachographs, both to improve the amount and quality of data, and the possibilities of tampering with the equipment. Electronic systems may possibly also be used for warning drivers to avoid violations. Conceivably, some time in the future the data from tachographs can be sent automatically to the authorities so that any violations will be detected immediately. A prerequisite for both warning and reporting systems is agreement about the interpretations of the regulations. This seems to be a limitation at present (Serafimovski, 1998).

- *Company safety policies and factors related to work organisation and working conditions*

It is important to focus on the role of the companies as well as the dispatchers to increase compliance with hours of service regulations, e.g. by setting up realistic delivery schedules, so that the drivers don't feel pressed to stretch the limits, but rather are motivated towards high compliance. Several companies have tried various kinds of reward systems to increase safety among their employees. Conceivably, such schemes could be implemented also in order to increase compliance with hours of service regulations, provided this is included in the companies' safety policy.

- *Better and more frequent facilities for resting during trips*

Drivers often complain about the resting and parking facilities, and maintain that this contributes to driving longer than allowed. It should therefore be considered to what extent improvements of such facilities may influence the drivers compliance with regulations.

- *Information to drivers regarding the risks related to prolonged driving and inadequate rest*

Many drivers are not sufficiently aware of the symptoms preceding falling asleep. These symptoms may also vary between individuals. Further, drivers often continue to drive even though they are clearly aware of being tired, because they believe it is possible to force oneself to stay awake even when tired. Special education of heavy-vehicle drivers might be useful, to increase the drivers' awareness of these problems, and motivate them to take the symptoms seriously. It is also important to correct the various myths that exist among drivers as to various means of keeping awake, which are actually inefficient or may at best work for a short while (loud music, opening the window, eating, drinking etc.)

An important fact is that sleepiness does not necessarily follow the rhythm implied in the hours of service regulations. Drivers may sometimes become extremely tired after only a short time behind the wheel, and sometimes they feel rested and awake at the time when regulations prescribe a break. It is therefore important that drivers are aware of symptoms preceding sleep, so that they can

take a break even if they are not required to do so. And this is also allowed for in the regulations, in that the required 45-min rest after 4.5 hours driving can be split up so that one or two 15-min breaks are taken earlier, and the final break is reduced correspondingly. If the regulations can allow more flexibility without increasing the workload and/or reduce the amount of rest and sleep, it may contribute to improved working conditions for the drivers, and probably also to traffic safety.

6 References

Andersson, G. 1989
Hastigheter som funktion av toleransgräns, övervakningsintensitet och påföljd. *VTI-rapport 337.* Linköping: Statens väg- och transportforskningsinstitut.

Andersson, L. 2003
Analys av regelefterlevnaden av EG`s kör- och vilotids regler för förare av tunga fordon. *Rapport YT10A 2003:2117.* Borlänge: Swedish National Road Administration - Sektionen för Kollektiv och Yrkestrafikk.

Andersson, L. and Serafimovcki, S. 2001
The European enforcement praxis. A report for the Swedish National Road Administration. Council regulation 3820/85 and 3821/85 and Council Directive 88/599/EG. *Technical Report L4i-01/381.* Stockholm: Industrilogik.

Arnedt, J.T., Wilde, G.J.S., Munt, P.W. and MacLean, A. W. 2001
How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis and Prevention* 33, 337-344

Arnold, P.K. and Hartley, L.R. 2001
Policies and practices of transport companies that promote or hinder the management of driving fatigue. *Transportation Research* 4F, 1-17

Arnold, P.K., Hartley, L.R., Corry, A., Hochstadt, D., Penna, F. and Feyer, A-M. 1997
Hours of work, and perceptions of fatigue among truck drivers. *Accident Analysis and Prevention* 29(4), 471-477

Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall, S. and Belenky, G. 2000
Effects of sleep schedules on commercial motor vehicle driver performance. Washington, US Department of Transportation. Report no DOT-MC-00-133

Brown, I.D. 1993
Driver fatigue and road safety. *Alcohol, Drugs and Driving* 9(3-4), 239-252

Brown, I.D. 1994
Driver fatigue. *Human Factors* 36(2), 298-314.

Baas, P.H., Charlton, S.G. and Bastin, G. T. 2000
Survey of New Zealand truck driver fatigue and fitness for duty. *Transportation Research* 3F(4), 185-193

Chen, C., Darko, E.O. and Richardson, T.N. 2003
Optimal continuous shoulder rumble strips and the effects on highway safety and the economy. *ITE Journal* 73(5), 30-41.

Dawson, D., Feyer, A-M., Grander, P., Hartley, L., Haworth, N. and Williamson, A. 2001

Options for regulatory approach to fatigue in drivers of heavy vehicles in Australia and New Zealand. Discussion paper from the Fatigue Expert Group

Elvik, R., Mysen, A.B. and Vaa, T. 1997
Trafikksikkerhetshåndbok. Oslo: Transportøkonomisk institutt.

European Transport Safety Council 2001
The role of driver fatigue in commercial road transport crashes. Brussels: European Transport Safety Council

Fairclough, S.H. and Graham, R. 1999
Impairment of driving performance caused by sleep deprivation or alcohol: A comparative study. *Human Factors* 41(1), 118-128

Feyer, A-M., Williamson, A.M., Jenkin, R. and Higgins, T. 1993
Strategies to combat fatigue in long distance road transport industry. The bus and coach perspective. *Report CR 122.* Australian Department of Transport and Communications.

Freund, D. and Vespa, S. 1997
US/Canada study of commercial motor vehicle driver fatigue and alertness. Paper presented at the Traffic Safety on Two Continents Conference. Lisbon, 22-24 September. *VTI konferens report 9A*, part 8, 71-84. Linköping: Väg och transportforskningsinstitutet.

Gårder, P. and Alexander, J. 1995
Fatigue related accidents and continuous shoulder rumble strips (CSRS). Transportation Research Board, 74th Annual Meeting.

Hamelin, P. 1987
Lorry drivers` time habits in work and their involvement in traffic accidents. *Ergonomics* 30, 1323-1333.

Hamelin, P. 1999
Drivers working hours in "Social aspects of road transport". Paris: ECMT.

Hanowski, R.J., Wierwille, W.W. and Dingus. T.A. 2003
An on-road study to investigate fatigue in local/short haul trucking. *Accident Analysis and Prevention* 35, 153-160

Hartley, L. (ed). 1995
Fatigue and driving. Driver impairment, driver fatigue and driving simulation. London: Taylor and Francis Ltd.

Hartley, L., Arnold, P.K., Penna, F., Hochstadt, D., Corry, A. and Feyer, A. M. 1996
Fatigue in the Western Australian transport industry: The principle and comparative findings. *Report number 117.* Perth: Institute for Research in Safety and Transport.

Haworth, N.L., Heffernan, C.J. and Horne, E.J. 1989
Fatigue in truck accidents. *Report no. 3.* Monash University Accident Research Centre.

Hensher, D.A., Battellino, H.C., Gee, J.L. and Daniels, R.F. 1991
Long distance truck drivers on-road performance and economic reward. *Report CR 99.* Australian Department of Transport and Communications.

Hertz, R. P. 1988
Tractor-trailer driver fatality: The role of non-consecutive rest in a sleeping berth. *Accident Analysis and Prevention* 20, 431-439.

Horne, J.A. and Reyner, L.A. 1995
Sleep related vehicle accidents. *British Medical Journal* 310, 565-567.

Horne, J.A., Reyner, L.A., Baulk, S.D. and Flatley, D. 2002
Driver sleepiness: Overview of recent findings from Loughborough sleep research centre. In: UK Department of Transport: *Behavioural research in road safety 2001*. Chapter 3.

Häkkänen, H. and Summala, H. 2000
Sleepiness at work among commercial truck drivers. *Sleep* 23(1), 49-57

Häkkänen, H., Summala, H., Partinen, M., Tiihonen, M. and Silvio, J. 1999
Blink duration as indicator of sleepiness in professional bus drivers. *Sleep* 22(6), 798-802.

Johns, M.W. 2000
A sleep physiologist's view of the drowsy driver. *Transportation Research Part F* 3(4), 241-249.

Justisdepartementet 2000
Ny instruks for kontroll etter forskrift om kjøre- og hviletider mv. ved innenlandsk transport og transport innen EØS-området. *Rundskriv G-74/00*. Oslo: Justisdepartementet.

Kerr, J.S. 1991
Driving without attention mode (DWAM): A formalisation of inattentive states in driving. I: Gale, A.G. *Vision in Vehicles, vol. III*., 473-479. Amsterdam: North-Holland.

Maycock, G. 1995
Driver sleepiness as a factor in car and HGV accidents. *TRL Report 169.* Crowthorne: Transport Research Laboratory.

McCartt, A.T., Hammer, M.C. and Fuller, S.Z. 1998a
Study of fatigue-related driving among long-distance truck drivers in New York State. Volume 1: Survey of long-distance truck drivers. New York: Institute for Traffic safety Management and Research

McCartt, A.T., Hammer, M.C. and Fuller, S.Z. 1998b
Study of fatigue-related driving among long-distance truck drivers in New York State. Volume 2: Analyses of crash data. New York: Institute for Traffic safety Management and Research.

McCartt, A.T., Hammer, M.C. and Fuller, S.Z. 1997
Speed and fatigued drivers. Research on the scope and nature of fatigued driving among truck drivers in New York State. Paper presented at the Traffic Safety on Two Continents Conference. Lisbon, 22-24 September. *VTI konferens report* 9A, part 8, 85-101. Linköping: Väg- och transportforskningsinstitutet.

McCartt, A.T., Wright, B.E., Rohrbaugh, J.W. and Hammer, M.C. 1999
High risk drivers. Causes of sleepiness-related driving among long-distance truck drivers including violations of the hours-of-service regulations. Paper presented at the Traffic Safety on Two Continents Conference. Malmö, 20-22 September. *VTI konferens report* 13A, part 2, 155-172. Linköping: Väg- och transportforskningsinstitutet.

Milosevic, S. 1997
Fatigue, work-related schedules and traffic safety. *Ergonomics* 40(3), 381-389.

Nairn, R.J. 1987
The role of fatigue in rural accidents. *Report GR/87/6*. Hawthorne, Victoria: Road Traffic Authority.

Nilsson, E. and Åberg, L. 1986
Övervakning och påföljd. TFD-forskning 1976-1983. *TFB-rapport 1986:11*. Stockholm: Transportforskningsberedskapen.

Norwegian Public Roads Administration 2003
Undersøkelse viser gode døgnhvilresultater. *Pressemelding av 24.02.2003*. Oslo: Vegdirektoratet.

Norwegian Public Roads Administration 2001
Kjøre- og hviletider. Regelverk, fortolkninger, praksis mv. *Håndbok 228.* Oslo: Vegdirektoratet.

Näätänen, R. and Summala, H. 1978
Fatigue in driving and accidents. *Driver fatigue in road traffic accidents. Contributions to workshops on physiological, psychological and sociological aspects of the problem*. EUR 6065, 26-32. Brussel: Commission of the European Communities.

Ouwerkerk, F. van 1987
Relationship between road transport working conditions, fatigue, health and traffic safety. *Report VK 87-01*. Groningen: Traffic Research Centre.

Ragnøy, A. and Sagberg, F. 1999
Vogntog, kjøreatferd og kjøretøytilstand. Betydningen av sjåførens arbeidssituasjon og rammebetingelser i næringen. *TØI rapport 468/1999.* Oslo: Transportøkonomisk institutt.

Ranney, T.A., Simmons, L.A. and Masalonis, A.J. 1999
Prolonged exposure to glare and driving time: effects on performance in a driving simulator. *Accident Analysis and Prevention* 31(6), 601-610.

Reyner, L.A. & Horne, J.A. 1998
Falling asleep whilst driving: are drivers aware of prior sleepiness? *International Journal of Legal Medicine* 111(3), 120-123.

Rikspolisstyrelsen 2002
Kör- og vilotider mm. Utskrift fra database for perioden 01.01.2001 til 31.12.2001.

Sagberg, F. 1999
Road accidents caused by drivers falling asleep. *Accident Analysis and Prevention* 31(6), 639-649

Schachter, D.L. 1976
The hypnagogic state: A critical review of the literature. *Psychological Bulletin* 83(3), 452-481.

Serafimovski, S. 1998
On the interpretation of the Council Regulation (EEC) 3820/85. A report for the Swedish National Road Administration. *Technical Report L4i-98/371.* Stockholm: Industrilogik.

Serafimovski, S. and Widebäck, F. 1999
Om tolkningen av rådets förordning (EEG) 3820/85. Volym 3: Den europeiska floran av tolkningar. *Technical Report L4i-99/441-s.* Stockholm: Industrilogik.

Storie, V.J. 1984
Involvement of goods vehicles and public service vehicles in motorway accidents. *TRRL Lab Report 1113.* Crowthorne: Transport and Road Research Laboratory.

Stutts, J.C., Wilkins, J.W. and Vaughn, B.V. 1999
Why do people have drowsy driving crashes: Input from drivers who just did. Washington D. C.: AAA Foundation for Traffic Safety.

Summala, H. and Mikkola, T. 1994
Fatal accidents among car and truck drivers: Effects of fatigue, age, and alcohol consumption. *Human Factors* 36(2), 315-326

Summala, H., Häkkänen, H., Mikkola, T. and Sinkkonen, J. 1999
Task effects on fatigue symptoms in overnight driving. *Ergonomics* 42(6), 798-806

Swedish National Road Administration 1998
Kör- och vilotider. Broschyr. Borlänge: Swedish National Road Administration.

Taoka, G.T. 1998
Asleep at the wheel: A review of research related to driver fatigue. *Transportation Quarterly* 52(1), 85-92.

Transportation Research and Marketing 1985
A report on determination and evaluation of the role of fatigue in heavy truck accidents. Prepared for American Automobile Association Foundation for Traffic Safety in cooperation with The commercial Vehicle Safety Alliance

UK Department of Transport 2002
Sleep-related vehicle accidents on sections of selected trunk roads and motorways in the UK (1995-1998). *Road Safety Research Report no 22*

Ulleberg, P. 2002
Influencing subgroups of young drivers and their passengers. Motivational influences of personality traits on risk-taking attitudes and driving behaviour. Doctoral dissertation, Norwegian University of Science and Technology (NTNU). *TØI Report 605/2002*. Oslo: Institute of Transport Economics.

US Department of Transportation 2000a
Effects of sleep schedules on commercial motor vehicle driver performance. Part 1. *TechBrief. Publication no. FMCSA-MCRT-00-014.* Washington: Federal Motor Carrier Safety Administration.

US Department of Transportation 2000b
Hours of service of drivers. Drivers rest and sleep for safe operations. Proposed rule. Part VI. *49 CFR Parts 350, 390, 394, 395 and 398.* Washington: Federal Motor Carrier Safety Administration.

US Department of Transportation 1970
Analysis and summary of accidents investigations. Washington, D.C.: Bureau of Motor Carrier Safety

US General Accounting Office 2000
Commercial motor vehicles. Effectiveness of actions being taken into improve motor carrier safety is unknown. *GAO/RCED-00-189.* Washington: United States General Accounting Office.

US National Transportation Safety Board 1990
Safety study. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the – driver heavy truck crashes (volume 1). *PB90-917002. NTSB/SS-90/01*

Wertheim, A.H. 1991
Highway hypnosis: A theoretical analysis. I: Gale, A.G. *Vision in Vehicles, vol. III*., 467-472. Amsterdam: North-Holland.

Williams, G.W. 1963
Highway hypnosis: An hypothesis. *International Journal of Clinical and Experimental Hypnosis* 11(3), 143-151.

Williams, G.W. and Shor, R.E. 1970
An historical note on highway hypnosis. *Accident Analysis and Prevention* 2, 223-225.

Williamson, A.M., Feyer, A. M. Friswell, R. and Sadural, S. 2001
Driver fatigue: A survey of professional long distance heavy vehicle drivers in Australia. *Information paper/Report CR 198.* Australian Transport Safety Bureau.

Williamson, A., Feyer, A-M. and Friswell, R. 1996
The impact of work practice on fatigue in long distance truck drivers. *Accident Analysis and Prevention* 28(6), 709-719.

Williamson, A., Feyer, A-M., Finlay-Brown, S. and Friswell, R. 2000a
Evaluating a regulated hours regime on-road and an alternative compliance regime under simulated conditions. *Report CR 190.* Australian Transport Safety Bureau.

Williamson, A., Feyer, A-M., Friswell, R. and Finlay-Brown, S. 2000b
Demonstration project for fatigue management programs in the road transport industry: Summary of findings. *Report CR 192.* Australian Transport Safety Bureau.

Williamson, A.M., Feyer, A.M., Coumarelos, C. and Jenkins, T. 1992
Strategies to combat fatigue in the long distance road transport industry: Stage 1 – The industry perspective. *Report CR 108.* Australian Transport Safety Bureau.

Åkerstedt, T. og Kecklund, G. 2000
Trötthet och trafiksäkerhet – en översikt av kunskapsläget. *Swedish National Road Administration publikation 2000:74.* Stockholm, Institutet för psykosocial medicin, Karolinska institutet.