DRIVER FATIGUE AND ROAD ACCIDENTS

A LITERATURE REVIEW
and
POSITION PAPER

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1 INTRODUCTION

1.1 Driver fatigue ('falling asleep at the wheel') is a major cause of road accidents, accounting for up to 20% of serious accidents on motorways and monotonous roads in Great Britain[1]. The Government's Road Safety Strategy, "Tomorrow's Roads: Safer for Everyone"[2], identifies driver fatigue as one of the main areas of driver behaviour that needs to be addressed if the target for reducing the number of people killed and seriously injured in road accidents by 40% by 2010 is to be achieved.

1.2 The purpose of this paper is to review published research and data concerning:

a) the scale of the sleep related road accident problem

b) the causes of driver fatigue

c) potential measures to reduce accidents caused by sleepy drivers.

1.3 This literature review is part of a DETR grant-in-aid project to develop a "Journey Planner for Drivers" and to investigate the feasibility of electronic route planners automatically prompting drivers to take rest stops on long journeys and, where possible, providing other safety-related information.

1.4 The literature research was conducted through RoSPA's Information Centre, a Transport 2000 CD-ROM and the internet. The main UK research considered in this report is the various studies into sleep related road accidents by Professor Horne at the Sleep Research Centre at Loughborough University, and TRL research. International studies, particularly from the USA, Australia, New Zealand and Canada, have also been considered.

1.5 For the purposes of this report the terms "sleepiness", "tiredness", "drowsiness" and "fatigue" are used interchangeably, unless otherwise stated.

2 SLEEP

2.1 Human beings need to sleep. Sleep is not a matter of choice; it is essential and inevitable. The longer someone remains awake, the greater the need to sleep and the more difficult it is to resist falling asleep. Sleep will eventually overpower the strongest intentions and efforts to stay awake.[3]

2.2 The need for sleep varies between individuals, but sleeping for 8 out of 24 hours is common, and 7 to 9 hours sleep is required to optimise performance. Sleep patterns are governed by the circadian rhythm (the bodyclock) that completes a full cycle approximately once every 24 hours. Humans are usually awake during daylight and asleep during darkness. There are two peaks of sleepiness: the early hours of the morning and the middle of the afternoon.[4]

2.3 The loss or disruption of sleep results in sleepiness during periods when the person would usually be fully awake. The loss of even one night's sleep can lead to extreme short term sleepiness, and continual disrupted sleep can lead to chronic sleepiness. The only effective way to reduce sleepiness is to sleep. Sleeping less than four hours per night impairs performance. The effects of sleep loss are cumulative, and regularly losing one or two hours of sleep a night can lead to chronic sleepiness over time.[5, 6]

2.4 Sleep loss and sleep disruption can be caused by a wide range of factors, some of which are beyond the individual's control, but some of which are personal choices:

- hours of work, including long hours and shift work
- family responsibilities
- social activities
- illness, including sleep disorders[3]
- medication
- stress.

2.5 Today's "24 hour society" seems to pressurise many people to sacrifice sleep in favour of other activities, without realising the negative effects this has on their health and ability to perform a wide range of tasks, including driving.

2.6 **Sleepiness and Impairment**
Sleepiness reduces reaction time (a critical element of safe driving). It also reduces vigilance, alertness and concentration so that the ability to perform attention-based activities (such as driving) is impaired. The speed at which information is processed is also reduced by sleepiness. The quality of decision-making may also be affected.[3]

3 DRIVER FATIGUE AND ROAD ACCIDENTS

3.1 There are difficulties in determining the level of sleep related accidents because there is no simple, reliable way for an investigating police officer to determine whether fatigue was a factor in an accident, and if it was, what level of fatigue the driver was suffering. This results in varying estimates of the level of sleep related accidents, and in particular, evidence based on accident reports usually produces lower estimated levels than research based on in-depth studies.

UK

3.2 A recent study by the Sleep Research Centre[1] indicates that driver fatigue causes up to 20% of accidents on monotonous roads. This suggests that there are several thousand casualties each year in accidents caused by drivers falling asleep at the wheel.

3.3 An earlier study[7] of road accidents between 1987 -1992 found that sleep related accidents comprised 16% of all road accidents, and 23% of accidents on motorways.

3.4 Research by the TRL[8] found slightly lower proportions of sleep related accidents: 9% - 10% of accidents on all roads, and 15% of accidents on motorways involved driver sleepiness. In this study, 29% of drivers reported having felt close to falling asleep at the wheel at least once in the previous twelve months.

3.5 An earlier (1984) TRL study[9], of 2,000 HGV and PSV drivers involved in accidents, found that driver fatigue was a factor in 11% of these accidents.

USA

3.6 In the USA, several studies[3,10-15] in recent years have produced various estimates of the level of sleep related road accidents. The National Highway Traffic Safety Administration (NHTSA) estimate that there are 56,000 sleep related road crashes annually in the USA, resulting in 40,000 injuries and 1,550 fatalities[3].

3.7 One study[10] calculated that 17% (about 1 million) of road accidents are sleep related. A 1995 study suggested that 2.6% of accidents caused by driver inattention were due to fatigue[11].

3.8 A study[12] of road accidents on two of America's busiest roads indicated that 50% of fatal accidents on those roads were fatigue related. Another study[13] claims that 30% - 40% of accidents involving heavy trucks are caused by driver sleepiness.

3.9 An analysis of road accidents between 1990 and 1992 in North Carolina[14] found 5,104 accidents in which the driver was judged to have fallen asleep. This was about 0.5% of all road accidents during that period. A survey[15] of 205 drivers in another State found that 31% admitted having dozed off at least once while driving during the preceding twelve months. Younger drivers were especially prone to doze off, and men were twice as likely as women to fall asleep at the wheel.

3.10 **Australia**

VicRoads, an Australian road safety organisation, estimates that 25% - 35% (and possibly up to 50%) of road crashes are sleep related[16]. A 1994 study[17], estimated that driver sleepiness accounts for 6% of road accidents, 15% of fatal accidents and 30% of fatal crashes on rural roads.

3.11 **Germany**

A study of motorway accidents in Bavaria[18] estimated that 35% of fatal motorway crashes were due to reduce vigilance (driver inattention and fatigue).

3.12 **New Zealand**

Between 1996 and 1998, 114 fatal road crashes (8% of all fatal crashes) and 1,314 injury road crashes (5% of injury accidents) were thought to be fatigue related.[19] A study[20] of 370 heavy motor vehicle crashes in 1997, found that driver fatigue was listed as a contributing factor in 7% of accidents.

3.13 **Norway**

A questionnaire survey[21] of 9,200 accident-involved drivers found that 3.9% of the accidents were sleep related, but almost 20% of night-time accidents involved driver drowsiness.

3.14 **Israel**

An assessment of road accidents between 1984 and 1989[22] found that up to 1% were recorded as sleep related, but the real figure was likely to be much higher as many accidents recorded as other types of driver error were likely to have been related to driver fatigue.

4 ACCIDENT PATTERNS AND RISK FACTORS

4.1 Type of Driver

4.1.1 Several studies have identified young male drivers, aged under 30 years, as one of the groups most at risk of being involved in sleep related road accidents. Horne[7] found that about half of the drivers involved in sleep related accidents were males aged below 30 years, with the peak age being 21 - 25 years.

4.1.2 Maycock[8] also found that young male drivers were at greater risk. This study identified company car drivers as having a high probability of falling asleep at the wheel because they tend to drive high mileage, on monotonous roads and have tight schedules.

4.1.3 A Danish study[23] found that tiredness was common among young male drivers who were driving at night.

4.1.4 American studies[3] have identified three main risk groups among drivers:

- male drivers aged 16 - 29 years
- shift workers
- people with sleep problems.

4.1.5 Another American study[15] found that 55% of sleep related crashes involved drivers aged 25 years or younger, with the peak age being 20 years.

4.1.6 Untreated sleep apnea (brief interruptions of air flow and loss of oxygen while sleeping, resulting in poor and fragmented sleep) and narcolepsy (a disorder of the sleep-wake mechanism which can cause excessive daytime sleepiness) increase the risk of sleep related driving accidents. Many people with these conditions are undiagnosed and untreated, and are unaware of their increased risk.[3]

4.2 Time of Day

4.2.1 Sleep related accidents peak in the early hours of the morning, between 2:00 and 6:00 am, and in the mid afternoon, between 3:00 and 4:00 pm, due mainly to circadian rhythms. Horne[24] calculated that drivers are 50 times more likely to fall asleep at the wheel at 2:00 am than at 10:00 am. The risk is three times as great between 3:00 - 4:00 pm than at 10:00 am.

4.2.1 There appears to be a link between the age of the driver and the peak fatigue time.[25] Younger drivers are more prone to fatigue in the early hours of the morning, whereas older drivers are more likely to fall asleep at the wheel during the afternoon sleep period. For drivers aged 70 years or more, the peak time period was between 10:00 and 11:00 am.

4.2.2 Maycock[8] also found a link between sleep related accidents and time of day, again with the highest risk period being the early hours of the morning.

4.2.3 American research[15] also shows the same time pattern of sleep related accidents related to the age of the driver. Those aged up to 45 years were more at risk in the early hours, those aged between 45 and 65 years were most at risk around 7:00 am, and those aged over 70 years the peak period was 3:00 pm.

4.3 Type of Journey

4.3.1 Journeys involving long periods of driving on monotonous roads, such as motorways, are more likely to result in a driver falling asleep at the wheel[25]. Journeys that are for work purposes, especially ones involving truck drivers or company car drivers, are also a high risk type of journey.

4.3.2 As discussed above, there is a clear relationship between time of day and the likelihood of falling asleep while driving. Therefore, journeys which involve driving in the early hours, and to a lesser extent in the middle of the afternoon, are likely to generate more risk.

4.3.3 Boredom; people who are under-stimulated tend to feel drowsy and more likely to fall asleep. [26]

4.4 Type of Road

4.4.1 As noted above, roads which involve sustained, monotonous driving, with little visual stimulus for the driver, and where drivers are not required to attend to either the vehicle's controls or respond to multiple road users and junctions, are more likely to have sleep related accidents. Urban roads are less prone to fatigue crashes because the level of activity is so much greater, and helps to keep drivers active and alert.[12]

4.4.2 Horne[7] found two-thirds of sleep related accidents occurred on A roads, 9% on motorways, 16% on B roads and 9% on minor roads.

4.4.3 Maycock[8] found higher rates on motorways (20%) and non built-up roads (14%) than on built-up roads (5%).

4.5 Other Impairment Factors

4.5.1 Lack of sleep is not the only cause of sleepiness. General health, alcohol, drugs, medicines and illness also cause tiredness, in addition to their other impairment effects. Most studies about driver fatigue exclude accidents where other impairment factors have been identified in order to isolate the effects of fatigue. However, sleepiness caused by alcohol or other drugs is still influenced by the circadian rhythm, so that the effects of the alcohol or drug are likely to be greater during peak periods of sleepiness (the early hours and mid afternoon).[3]

4.5.2 Research at Loughborough University shows that drinking alcohol in the early afternoon is about twice as likely to make a driver sleepy than the same amount drunk in the early evening.

4.5.3 Recent research[27] in Australia and New Zealand suggests that staying awake for 17 - 19 hours results in the same level of impairment as drinking around 50 mg of alcohol, and produces much slower response speeds.

4.6 Type of Accident

4.6.1 Sleep related accidents tend to be more severe, possibly because of the higher speeds involved and because the driver is unable to take any avoiding action, or even brake, prior to the collision[3]. Horne[7] describes typical sleep-related accidents as ones where the driver runs off the road or collides with another vehicle or an object, without any sign of hard braking before the impact.

4.6.2 Horne[7] also suggests that the risk of death or serious injury to drivers may be greater in sleep related accidents than in other types of accident. A study of accidents in North Carolina also concluded that sleep related accidents tended to have more severe consequences.[14]

4.6.3 Zomer[22] found that the number of casualties in sleep related accidents was 50% higher than in all accidents, and sleep accidents had three times as many fatalities, and twice as many serious injuries, than non sleep related accidents.

4.6.4 Indications that an accident is sleep related are that :

- a single vehicle left the road
- the accident occurred on a high speed road
- the driver did not attempt to brake or swerve to avoid the accident
- the driver was alone in the vehicle
- the accident occurred in the early hours of the morning, or between 3:00 and 4:00 pm.

5 WORK RELATED FATIGUE ACCIDENTS

5.1 Truck Drivers

5.1.1 Driver fatigue is a particular problem for truck drivers. A 1998 American study[28] found that about 20% of all fatal crashes and fatalities and 10% of all injuries involving a long-haul truck, occurred between midnight and 6 a.m, the peak period for driver fatigue. These crashes tended to be more severe than crashes during other parts of the day. Truck driver fatigue was a particular problem in single-vehicle fatal crashes, but in crashes involving other vehicles, fatigue was coded more often for the other driver than for the truck driver.

5.1.2 In another study, 593 truck drivers were interviewed at rest areas on New York's interstate highways[29]. Nearly two-thirds reported episodes of drowsy driving within the previous month, and almost 5% said that they drove when drowsy on most, if not all, days. Nearly half had fallen asleep at the wheel at some point in their driving career, and about one-quarter reported doing so at least once during the previous year.

5.1.3 Truck driver fatigue may be a contributing factor in as many as 30% to 40% of all heavy truck accidents.[30]

5.1.4 For a two year period large truck crashes on the interstate system in Washington State were investigated using a case-control method[31]. For each large truck involved in a crash, three trucks were randomly selected for inspection at the same time and place as the crash. Driving in excess of eight hours increased the risk of crash involvement by a factor of two; drivers with log book violations, young drivers, and interstate drivers also had increased crash risks.

5.1.5 Similar evidence in relation to those who operate and/or manage other modes of transport, such as trains, ferries and aircraft indicates a correlation with the research into trucks and driving.

5.2 Drivers' Hours

5.2.1 In most countries, HGV and PSV drivers are subject to regulations that set limits on the amount of time they can drive without a break, the amount of time they can drive in a day, the amount of time they can be on-duty and for minimum rest periods. These regulations are designed to prevent drivers from driving for unreasonably long periods and consequently falling asleep at the wheel. However, they still allow drivers to drive for very long periods (E.U. Drivers Hours Rules, for instance, allow drivers to drive up to 4.5 hours without a break, and even this can be extended).

5.2.2 Driver Hours regulations are flawed in other respects. In America, they have been criticised for actually increasing risk because they do not take account of circadian rhythms and so sometimes require a driver to rest when wide awake, and to drive when sleepy.[32] Horne[25] points out that the EU Drivers Hours do not appear to be based on any evidence of safe driving times.

5.2.3 One of the studies by Horne[7] found that all of the sleep related HGV accidents occurred within two hours of the start of the journey. An analysis[33] of more than one thousand commercial vehicles in Europe found that most truck accidents take place in the first seven hours of the driving time.

5.2.4 Discussions are underway in the EU on the possibility of extending the Working Time Directive (which sets limits on the amount of working, as opposed to driving, time) to cover drivers and operators who are currently covered by the Drivers Hours Rules. In its Road Safety Strategy[2], the British Government states that once the results of the EU discussions are known, it will consult on repealing the UK Domestic Drivers Hours Rules in favour of the EU Rules.

5.2.5 Even the limits set by the Drivers Hours Regulations are often flouted by operators and drivers. And many classes of drivers are not covered by these regulations. Van, taxi and company car drivers do not have legal limits on their driving time. An Australian survey[34] showed that about 38% of truck drivers exceeded 14 hours of driving in a work day, and another 5% exceeded 14 hours of work (including non-driving work). About 5% of drivers reported having not slept and 7.5% reported less than four hours of sleep on at least one work day of the preceding seven days. Overall, about one third of drivers obtained less than six hours of sleep on at least one working day.

5.2.5 In America, almost 20% of drivers reported that they "always or often" exceeded the 10-hour driving limit in the Federal Highway Administration Hours-of-Service (HOS) regulations. Close to one-fifth were usually off-duty for fewer than eight hours, and just over 21% drove longer than their records indicated.[29]

5.2.6 Another study[35] found significantly higher fatigue accident rates for drivers who drove for longer than 9.5 hours per day without rest, for driving at night, and for driving in remote areas. These factors were found to have a cumulative effect on fatigue-related truck accident rates.

5.2.7 A New Zealand study[36] compared a group of heavy vehicles involved in crashes (for which details of drivers' hours were known from their log-books) with a matched control group of similar vehicles. There was an increased crash risk when driving hours since the driver's last compulsory 10 hour off-duty period exceeded about eight hours.

5.2.8 The Australian study referred to above (5.2.5)[34] found that 67% of truck drivers with irregular schedules had been involved in fatigue-related accidents, compared to 38% of drivers with regular schedules. 82% of the drivers who admitted to having exceeded the number of permissible driving hours had had a fatigue-related accident. The most important measures in predicting a fatigue-related accident in the sample were the duration of the last sleep period, the total hours of sleep obtained during the 24 hours prior to the accident, and the split sleep patterns.

5.2.9 A study[32] of schedules of 498 long-distance drivers found that, assuming average legal speed limits of 55 mph, 26% of the drivers had schedules that required them to exceed speed limits in order to meet the schedule. Assuming average travelling speeds of 50 mph, the vast majority of long distance drivers would have to work more than 40 hours a week, half would work more than 65 hours and a quarter over 81 hours a week.

5.2.10 An informal truck driver ‘Pooling’ system is known to operate in UK, in which (usually self-employed) drivers are ‘called-off’ by large operators as and when required. It is understood that this enables individual drivers to work far longer than would be legally possible if they were employed by a single employer. Such practice, while obviously attractive to commercial operators because it enables them to pay only for the hours or trips they need, leaves much to be desired in safety terms, since the drivers may well have already worked a full quota of hours for other companies before they start the next job.

5.3 Shift Work

5.3.1 Shift workers are more likely to have less sleep, and sleep disturbances, than non shift workers. Disruptions to the circadian rhythm are associated with impaired attention and performance and slower reaction times.[3]

5.3.2 An investigation[37] of the rate of road accidents related to sleep duration in 448 shift nurses found that road accidents occurred more frequently on the way home from morning and night shifts. Those nurses who reported accidents generally slept less than their colleagues. Another study compared nurses on rotating shifts with nurses on other schedules and found that those on rotating shifts reported more accidents (including driving accidents).[38]

5.3.3 A USA survey[39] of rotating shift and straight day workers at a manufacturing plant found an increased incidence of motor vehicle accidents or 'near misses' in which sleepiness was cited as a cause: 22% of rotating shift workers compared to 7% of day-only workers. Complaints of poor sleep and increased sleepiness during hours of wakefulness were also significantly more common in shiftworkers than day workers. Shiftworkers reported higher caffeine and alcohol consumption, and were more likely to use alcohol as a sleep aid.

5.3.4 Another study[40] found that there were few differences in alertness during work hours, but that 12 hour shift workers were significantly more sleepy at the end of the shift, especially at 7:00 am., than eight hour shift workers. Such workers were particularly at risk when driving home after their shift.

5.4 Passenger Carrying Vehicles

5.4.1 Taxi and private hire car drivers also often work very long hours, although they are more likely to drive in urban environments where the risk of falling asleep at the wheel is less. However, they often work shifts, and in the early hours of the morning which increases their risk.

5.4.2 An Australian study[41] examined fatigue-related variables and their relationship with accident involvement in a group of 42 Sydney metropolitan taxi drivers over a two-year period. The authors found that driver time-on-the-road is often considerable: 67% of those surveyed drove at least 50 hours per week, yet time off in long shifts (up to 12 hours) was often short (as low as 3 minutes, with an average of 37 minutes).

5.4.3 Bus and coach drivers often drive for long distances on monotonous roads, work long shifts, all of which are high-risk factors as far as fatigue-related accidents are concerned. Although the hours of work associated with this activity take account of periods when the driver is not driving, it may not always be possible for the driver to 'rest' properly during these driving breaks and this casts doubt over the drivers' hours regime. However, no studies focusing on bus and coach drivers were identified.

5.4.4 The informal 'driver pooling' system referred to in 5.2.10 is also understood to operate in this field. Bus and coach drivers sometimes work for more than one transport company, and it is understood that some are engaged in other types of work as well (such as taxi/private hire vehicle driving or night-shift work).

5.4.5 Drivers (other than professional drivers), who drive (usually) smaller vehicles, such as minibuses or people carriers, do not fall within the regulations even though they may be carrying passengers who are dependent upon their ability to drive safely over extended distances and periods of time. Examples of such drivers include teachers, youth workers' people working in the youth uniformed organisations, churches and community centres. No regulations cover this type of driving, nor are there yet guidelines from Government on this issue.

5.5 Managing Occupational Road Risk

5.5.1 It is clear that many types of vocational drivers have driving patterns that are associated with sleep related accidents. Therefore, employers have a major role to play in reducing the risk of their employees falling asleep at the wheel while driving for work. The adoption and implementation of the principles of the Management of Occupational Road Risk[42] provide many opportunities for employers to reduce this risk, principally by ensuring that they assess which drivers and journeys are at risk and set schedules that do not require drivers to exceed driver hours, and speed limits.

5.5.2 Principally, employers should:

- Manage the safety of their employees who drive
- Consider and implement the most suitable system of risk assessment and re-assessment for the road safety needs of the company and its employees
- Choose the right vehicle and the safest specification for the needs of the job
- Ensure that work practices, journey schedules, appointments and routes enable drivers to stay within the law
- Provide sensible guidelines about driving and for the use of the vehicles for all employees who may drive for the company.

6 DRIVER AWARENESS

6.1 Drivers are normally aware when they are feeling sleepy, and therefore make a conscious decision about whether to stop and rest or to continue driving while trying to fight off sleepiness and stay awake.

6.2 Horne has demonstrated that most drivers involved in sleep related accidents, deny having fallen asleep. This may be due to embarrassment, fear of prosecution or loss of insurance indemnity, or to a genuine belief that they did not fall asleep. Laboratory studies have shown that if people are woken within a few minutes of falling asleep, they will have no knowledge of having fallen asleep. [24]

6.3 However, even if drivers are genuinely unaware of having fallen asleep, they are fully aware of feeling sleepy beforehand. Horne used a driving simulator on which subjects whose sleep had been restricted to five hours the night before, drove for two hours in the afternoon on a monotonous road, to assess awareness of sleepiness while driving, awareness of the likelihood of falling asleep during the drive and the level of incidents due to sleepiness while driving. The study showed that drivers were well aware when they were feeling sleepy, and generally were aware that this meant they might fall asleep.

6.4 The number of incidents increased as drivers grew more sleepy, and all the major incidents (where the car drifted out of the lane completely) occurred after a lengthy period in which the driver was aware of increasing sleepiness, and usually after a period of fighting sleepiness.

6.5 Some drivers did not seem to realise that feeling very sleepy meant that they were likely to actually fall asleep.

6.6 Another study[25] by Horne suggested that people often fall asleep more quickly than they realise or expect.

7 DRIVERS' TACTICS TO AVOID FALLING ASLEEP

7.1 Given that drivers are usually aware that they are feeling sleepy, many employ a range of strategies to help themselves fight sleep and to stay awake. Maycock[8] asked drivers to list the tactics they use.

Open windows/turn up air conditioning	68%
Stop and go for a walk	57%
Listen to radio/cassette	30%
Talk to a passenger	25%
Drink coffee	14%
Other	15%

7.2 A series of studies at the Loughborough University Sleep Research Centre assessed the effectiveness of these measures, and found that the only ones that had any effect (beyond a very short term 10 - 15 minutes) were an intake of caffeine of at least 150 mg and a nap of around 15 minutes.

7.3 **Listening to the Radio**
Subjects who had been restricted to five hours sleep the night before drove on a driving simulator for 2.5 hours on monotonous roads. Listening to the radio had no significant effect in reducing sleepiness or in reducing 'incidents' (i.e. drifting out of lane), other than for an initial, very short, 10 to 15 minutes. [43]

7.4 **Air Conditioning**
The same study[43] assessed the effects of air conditioning, but also found no significant benefit.

7.5 **Exercise**
A study[44] examining whether exercise can help to reduce sleepiness compared the effects of 10 minutes light, 10 minutes moderate and 10 minutes heavy exercise. Light and moderate exercise made some of the subjects feel less sleepy, but only for about 10 minutes. Heavy exercise produced better results, and the effects lasted for about 30 minutes. However, it does not seem feasible for people to take heavy exercise during breaks from journeys, or indeed as preparation for a journey. Therefore, exercise is not a practical way of avoiding or reducing driver sleepiness.

Caffeine

7.6 A trilogy of studies [45-47] assessed the effects of caffeine intake on driver sleepiness using a driving simulator. The first[45] found that it takes around 30 minutes for caffeine to take effect but that taking 150mg of caffeine in the early afternoon was effective in reducing sleepiness, and sleep related 'incidents', for up to one hour.

7.7 A second study[46] found that combining 150 mg of caffeine with a nap of around 15 minutes significantly reduced sleep related incidents for up to two hours, compared to subjects who had taken a placebo (decaffeinated coffee).

7.8 The third study[47] examined the effects of taking 200 mg of caffeine on a group of drivers who had only slept five hours the night before, and on a group who had no sleep the previous night. Again, for the group who had restricted sleep, the caffeine took around 30 minutes to take effect, but then significantly reduced sleep related incidents for the next two hours. However, there was no such effect for the group who had no sleep. In fact, the driving of this group was so impaired that they were unable to continue driving on the simulator for more than one hour. The caffeine had some effect for the first 30 minutes, but this deteriorated markedly thereafter.

Naps

7.9 Horne[46] reports that various studies have shown that taking a nap can reduce impairment caused by sleepiness, and that the minimum nap time required to gain any benefit is 4 minutes, but naps of 20 minutes or more tend to be counter-productive. The optimum nap period is 15 minutes.

7.10 Two of the studies [46-47] referred to above also examined the benefits of taking a nap, (in addition to examining the benefits of caffeine intake) and found that taking a 15 minute nap was as effective as taking 150 mg of caffeine. The second study found that combining a nap and caffeine was particularly effective.

Conclusion

7.11 Most of the things that drivers do to fight off sleepiness when driving are ineffective for more than around 10 minutes. They are only useful in an emergency to provide time for the driver to find somewhere safe to stop and rest.

7.12 The only measures that have an effect in reducing sleepiness when driving are taking a nap of around 15 minutes and taking at least 150 mg of caffeine. However, even these measures are no substitute for sleep. And there is some concern that drivers may use these tactics to enable themselves to continue driving when they should really stop.

7.13 It is clear that while drivers are aware that they are becoming sleepy, and that this increases their risk of having an accident, many will persevere with their driving, and employ a number of measures to fight off sleepiness.

7.14 Education and publicity measures are required to raise awareness amongst drivers of the dangers of driver fatigue. Such measures could focus on:

- the dangers of driving when tired and the consequences of falling asleep
- the signs that a driver is becoming too tired to continue driving
- the ineffectiveness of common tactics (such as listening to the radio)
- the relative effectiveness of caffeine and naps
- the need to plan journeys
- the need to rest well before long journeys
- the increased risk that illness, alcohol, drugs and medicines generate
- the types of journeys that carry the highest risk.

8 HIGHWAY ENGINEERING

8.1 Much of the research into driver fatigue has identified that dull, monotonous roads increase the risk of sleep related accidents. Unfortunately, it is not feasible to design roads, such as motorways, that are stimulating to drive along. However, there are some highway design and engineering measures that can be used successfully.

Hard Shoulder Rumble Strips

8.2 As sleep related accidents often involve a vehicle drifting out of lane, it is thought that rumble strips along the edge of a road, and particularly along the hard shoulder of motorways, may wake up a drowsy driver and so avoid an accident.

8.3 In the USA, an innovative rumble strip called the Sonic Nap Alert Pattern (SNAP) was developed and installed on the highway shoulder of the Pennsylvania Turnpike[48]. A distinct warning sound and vibration are produced when drowsy or inattentive drivers' vehicles drift to the right and their tyres roll on the strips. After installation of SNAP, drift-off-road accidents per month decreased by 60% - 70%.

8.4 A 1994 study[15] of continuous shoulder rumble strips (CSRS) in 34 states that used CSRS along at least parts of their freeway systems, and some other roads, concluded that CSRS can reduce run-off-road accidents by 20% to 50%.

8.5 Concern in Japan about accidents, particularly involving truck drivers, caused by the driver falling asleep resulted in the development of a striped road surface design to help keep drivers awake at the wheel. This was used at locations where accidents probably caused by drowsy drivers were frequent. Accidents in these locations were reduced to zero where previously there had been two or three per month[49].

8.6 In the UK, the use of continuous raised rib markings is governed by the Traffic Signs and General Directions regulations 1994, and the DETR provide advice and guidance on their use in Traffic Advisory Unit leaflets[50].

9 IN-VEHICLE TECHNOLOGY

9.1 Devices to detect when drivers are falling asleep and to provide warnings to alert them of the risk, or even to control the vehicle's movement, have been the subject to much research and development. Some are designed to monitor the driver and detect changes in, for example, blink rates or head position. Others detect changes in vehicle movement, such as drifting out-of-lane. However, there are concerns about the reliability of such devices and that drivers may rely on them to warn them when the situation becomes particularly dangerous rather than consider and plan when they should take rest breaks. It has been shown that drivers are normally well aware that they are sleepy, so why is a device necessary to tell them so?

9.2 An analysis of collision warning devices[51] found that a system which only alerted a driver to a potential accident due to an unintentional lane change or roadway departure was not likely to be cost effective. However, a system which could also warn of potentially hazardous situations when other manoeuvres were being made could be very beneficial.

9.3 One study[52] assessed whether degradation in driver performance could be detected from controlled inputs of drowsy drivers. A test was developed to replicate the kind of driving environment associated with single vehicle run-off-the-road type crashes. Physiological measures of drowsiness were recorded on a closed-circuit track. Driving sessions were conducted when test subjects were both alert and sleep deprived. The results indicated that lane departure, arising from a loss of alertness due to fatigue, may be predicted by monitoring movements of the steering wheel.

9.4 An evaluation of the Safe-T-Cam System[53], where passive image processing has been used to monitor the movement of heavy vehicles indicated that on average such a system could reduce excessive driving hours by over 3%, and excessive speed by over 2%. Additional morale benefits were improvements to company image, driver education and awareness of safety, and to vehicle on-road/time efficiency.

9.5 A variation on devices to detect drowsiness is a device to help maintain alertness. An experiment[54] was conducted using a driving simulator to assess whether drivers' alertness could be maintained in drowsiness-inducing conditions by a 'gamebox'. When driving with the gamebox, drivers reported a lower degree of drowsiness and fewer instances of sleep episodes as compared to a control condition. Driving with the device resulted in fewer incidents and accidents, and those that did happen, occurred later in the session. The quality of vehicle control deteriorated progressively over the course of the session, but less so in the gamebox condition.

9.6 An evaluation[55] of three fatigue monitors (an eye closure monitor, a head nodding monitor and a reaction time monitor) suggested that the devices showed an ability to detect fatigue in some cases but were not able to maintain alertness and thus prevent performance deterioration. There were a few instances of the audible alarms startling the driver.

9.7 Evidence from the field of rail transport indicates that the use of a stimulus/ action response system is likely to improve driver attentiveness and thus safety. In further refinements, when it was linked to existing vehicle systems (viz. the brakes) so that when the driver failed to respond to the stimulus, or responded inappropriately, the brakes were applied, it proved ‘fail-safe’.

10 CONCLUSION

10.1 Driver fatigue is a serious problem resulting in many thousands of road accidents each year. It is not currently possible to calculate the exact number of sleep related accidents because of the difficulty in detecting whether fatigue was a factor and in assessing the level of fatigue. However, research suggests that up to 20% of accidents on monotonous roads in Great Britain are fatigue related. Research in other countries also indicates that driver fatigue is a serious problem.

10.2 Young male drivers, truck drivers, company car drivers and shift workers are the most at risk of falling asleep while driving. However, any driver travelling long distances or when they are tired, is at risk of a sleep related accident. The early hours of the morning and the middle of the afternoon are the peak times for fatigue accidents, and long journeys on monotonous roads, particularly motorways, are the most likely to result in a driver falling asleep.

10.3 It is clear that drivers are aware when they are feeling sleepy, and so make a conscious decision about whether to continue driving or to stop for a rest. It may be that those who persist in driving are either unaware of the risk they are taking, or underestimate the risk of actually falling asleep while driving. Or it may be that some drivers choose to ignore the risks (in the way that drink drivers do). However, this awareness at least provides a foundation on which to build educational messages.

10.4 Most of the things that drivers do to try to keep themselves awake and alert when driving are ineffective, and should only be regarded as emergency measures to allow the driver time to find somewhere safe to stop. Drinking at least 150 mg of caffeine and taking a nap of around 15 minutes are the only measures that help to reduce sleepiness. But even these are temporary measures; sleepiness will return if the driver does not stop driving within a fairly short period of time.

10.5 The safest option is for drivers to avoid driving when sleepy, when they would normally be sleeping or when they are ill or taking medication which contra-indicates driving or using machinery. It is crucial that drivers plan journeys, especially long ones involving driving on motorways or other monotonous roads. Drivers should:

- Try to ensure they are well rested, and feeling fit and healthy (and not taking medication which contra-indicates using machinery), before starting long journeys
- Plan the journey to include regular rest breaks (a break of at least 15 minutes at least every two hours)
- If necessary, plan an overnight stop
- Avoid setting out on a long drive after having worked a full day
- Avoid driving into the period when they would normally be falling asleep
- Avoid driving in the small hours (between 2am and 6am)
- Be extra careful when driving between 2pm and 4pm (especially after having eaten a meal or drunk any alcohol)
- If feeling sleepy during a journey, stop somewhere safe, take drinks containing caffeine and take a short nap.

10.6 Employers have a vital role to play in managing the risks involved in their employees who drive for work purposes. As part of their health and safety policies and practices, employers should adopt and implement the principles of managing occupational road risk, with particular reference to reducing the risk of their employees being involved in a sleep related driving accident. Principally, employers should:

- Manage the safety of their employees who drive
- Consider and implement the most suitable system of risk assessment and re-assessment for the road safety needs of the company and its employees
- Choose the right vehicle and the safest specification for the needs of the job
- Ensure that work practices, journey schedules, appointments and routes enable drivers to stay within the law
- Provide sensible guidelines about driving and for the use of the vehicles for all employees who may drive for the company.

10.7 **Holiday and Travel Companies**

One of the times when individual drivers may drive in the early hours of the morning is when they are catching, or returning from, an early flight or ship/ferry journey. Drivers returning from long haul flights, or coming off ships and ferries also often drive home after having had very little sleep in the previous 24 hours. Holiday companies, airlines and shipping lines should consider what advice and information they could offer to their customers, particularly as they sell alcohol to their passengers, which exacerbates the risk.

10.8 **Enforcement**

It can be difficult for the Police to detect a fatigue-impaired driver. However, some Police Forces are currently trialling general impairment roadside tests, which may prove effective in detecting sleepy drivers, as well as drivers affected by alcohol, drugs or medicines.

10.9 The regulation and enforcement of driver hours rules is obviously important. However, these rules do not cover many drivers who drive for work (e.g. company car drivers) and who do very high mileages. Even some of those drivers and operators who are governed by the Rules, sometimes find way of circumventing them. It would be difficult to include non-vocational drivers within the regulations because their vehicles are not currently required to have tachographs. However, it may be that technological advancements in the long term would enable motor vehicles (with a few exemptions) to have some form of system that records and maintains a record of an individual’s driving hours, no matter what vehicle they are driving. Whether this would be publicly or politically acceptable is another issue. In the meanwhile, guidance could be developed for employers on drivers’ hours that mirrored the existing regulations.

10.10 **Technical Devices**

Technical devices to detect when drivers are feeling sleepy and provide warnings to them, or even to take control of the vehicle, are being researched and developed. Such devices may prove beneficial, but there are concerns that drivers would rely on them instead of managing themselves for safety.

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