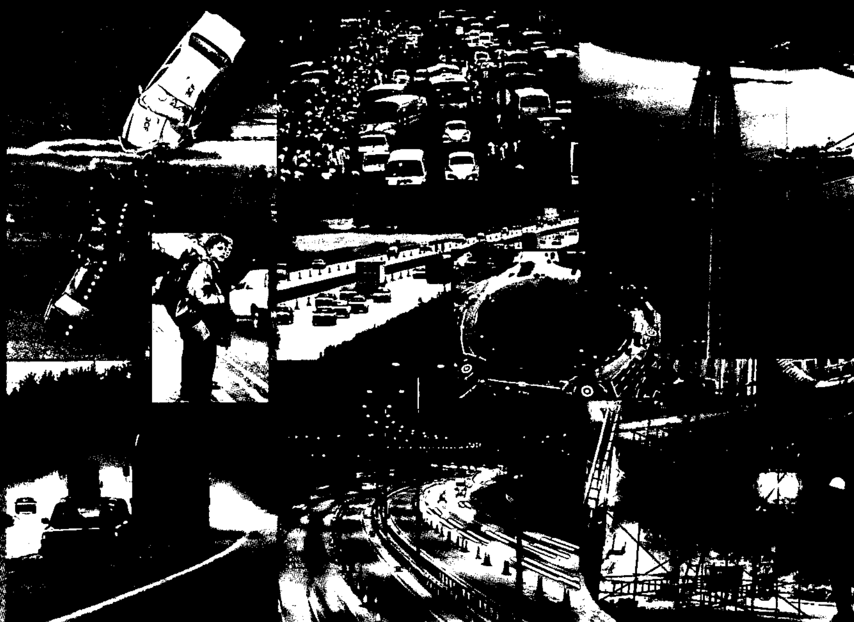

Driver sleepiness as a factor in car and HGV accidents

by G Maycock

An executive agency of THE DEPARTMENT OF TRANSPORT

TRL Report 169

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TRL REPORT 169

DRIVER SLEEPINESS AS A FACTOR IN CAR AND HGV ACCIDENTS

by G Maycock

Prepared for: Project Record: S2/11M/RB Fatigue and Driving
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EXECUTIVE SUMMARY

INTRODUCTION

Driver 'fatigue' is often cited as a cause of road accidents. Although the identification of sleep related accidents is difficult, the evidence from 'in-depth' studies, suggests that sleep may be a factor in between 10 and 25 per cent of accidents. Studies that use 'officially reported' accident data produce estimates of the involvement of fatigue in accidents ranging from 0.5 - 3.7 per cent.

In order to obtain information about fatigue or sleepiness as a factor in accidents from the drivers themselves, two surveys have been undertaken - one an interview survey of male HGV drivers and the other a postal questionnaire survey of male car drivers. The surveys were designed to determine the relationship between an individual's tendency to daytime sleepiness as measured by a scale known as the 'Epworth daytime sleepiness scale' and accident involvements.

THE HGV DRIVER SURVEY

In the survey of HGV drivers, just under 1000 HGV drivers were interviewed. Drivers were asked about their age, driving experience and annual mileage, and about the accidents they had experienced in the last three years. Each driver completed the Epworth sleepiness scale. Medical evidence suggests that there are certain physical factors which can in some individuals impair breathing during night-time sleep, resulting in excessive daytime sleepiness. These factors are obesity (particularly excess fat around the neck) and propensity to snore heavily during night-time sleep. Accordingly, drivers were asked about their propensity to snore at night, and the interviewers made subjective assessments about whether the drivers were obese and whether they had a large collar size.

The sample of drivers (996 in all) were evenly spread across the 20 - 60 age range; the average age was just over 41. The drivers covered an average of 69,700 miles per year, two thirds of which was on motorways. 205 of the drivers reported 252 accidents over a 3-year period.

The main findings of the survey may be summarised as follows: (i) there was no statistically significant relationship between accident frequencies (accidents per 3-year period) and annual mileage or percentage of driving time spent on motorways; (ii) accident frequencies are strongly dependent on the age of the driver - drivers in the 17-29 year old age group average 0.44 accidents in a 3-year period compared with 0.15 accidents per 3-years for drivers aged over 55; (iii) the accident liabilities of the 37 per cent of drivers who either snored every night or who were judged by the interviewers to have a large collar size (factors which might predispose them to impaired night-time sleep) were sensitive to daytime sleepiness as measured by the Epworth daytime sleepiness scale; drivers with these characteristics who score 12 on the Epworth scale (approximately the 95th percentile point of the distribution) have an accident liability which is twice that of drivers who do not suffer from excessive daytime sleepiness. The reasons for this result need further investigation.

THE CAR DRIVER SURVEY

The postal questionnaire survey of male car drivers was based on just over 4600 responses from a structured sample of 9000 drivers. In addition to questions about age, exposure, occupational group and propensity to snore, drivers were asked about the accidents in which they had involved in the last three years of driving; they were also asked whether 'tiredness' had contributed to any of these accidents. Drivers completed the Epworth Sleepiness Scale, and indicated whether or not they had felt close to falling asleep at the wheel in the last 12 months. Because company car drivers drive larger distances than private car drivers - a higher proportion of which is on motorways - it seemed possible that company car drivers would be particularly vulnerable to the effects of tiredness. Drivers were therefore asked whether they drove a privately owned car or a company owned car most often. All drivers were asked to report the methods they had found helpful in countering the effect of sleepiness whilst driving.

The average age of the study sample was 48; 83 per cent of the sample mostly drove privately owned cars, and 17 per cent drove company owned cars; the average annual mileage covered by drivers in this survey was 11,380.

TIREDNESS AND DRIVING

29 per cent of drivers reported having felt close to falling asleep at the wheel in the past 12 months. A logistic model showed that a number of characteristics including Epworth score, age and exposure, are influential in predicting the probability of feeling close to falling asleep at the wheel. Depending on these factors, the probability can range from below 0.1 to over 0.9.

The principal methods suggested by drivers for countering the effects of sleepiness were: opening the window for fresh air (68 per cent), stopping and taking a walk (57 per cent), listening to the radio (30 per cent) and talking to a passenger (25 per cent). Drinking coffee was a countermeasure advocated by only 14 per cent of the drivers.

Tiredness was reported as being a factor in 7 per cent of the accidents in which the survey drivers had been involved. Making allowance for the fact that about one third of accidents involve two cars, the 7 per cent of tiredness related involvements probably means that tiredness is implicated in between 9 and 10 per cent of accidents. Tiredness as a contributory factor in accident involvements differed significantly by type of road, age and time of day.

ACCIDENTS AND ACCIDENT LIABILITY

The overall accident involvement frequency (accidents in the last 3 years uncorrected for any accidents which may have been forgotten) was 0.217. The results of the analysis of accident liability may be summarised as follows: (i) accident frequencies fell with increasing age, from just under 0.4 accident involvements in 3 years for the 17-24 year old age group to just under 0.13 involvements per 3 years for over 65 year old drivers, (ii) accident frequencies increase with both annual mileage and frequency of trip making, (iii) those private car drivers who have felt close to falling asleep whilst driving, have an accident liability at the upper end of the Epworth scale which is a factor of 1.38 higher those scoring zero on the Epworth scale. Company car drivers who have felt close to falling asleep at the wheel, have an accident liability at high Epworth scores which is 1.7 times that of a driver who scores zero on the Epworth scale. Those company car drivers who have felt close to falling asleep at the wheel and who snore every night (indicative perhaps, as in the case of HGV drivers, of impaired night-time sleep) and who suffer from daytime sleepiness (high Epworth scores), have an accident liability which is three times that of those who do not suffer from excessive daytime sleepiness.

CONCLUSION

It has always proved difficult from more traditional sources of accident data to identify the contribution of fatigue to accidents. The car drivers in this study are suggesting that tiredness is a contributory factor in 7 per cent of accident involvements (estimated to be the equivalent of between 9 and 10 per cent of accidents).

HGV drivers were not asked about falling asleep at the wheel, nor were they asked to assess whether fatigue was a contributory factor in the accidents in which they were involved. However, in the case of both HGV and car drivers, the evidence provided by the accident analysis reported here for a positive relationship between accident frequency and Epworth score for some drivers, provides a convincing indication that sleepiness is indeed a significant factor in accidents. The role of the company car driver is also clear and dominant. Company car drivers have a particularly high probability of falling asleep at the wheel and a relatively high accident frequency. The fatigue countermeasures suggested by the drivers included opening a window, taking a walk, listening to the radio and drinking coffee. It is clearly necessary in future research to determine as objectively as possible, the relative effectiveness of these (and other) potential countermeasures so as to be in a position to be able to give sound practical advice to drivers who find themselves in a position of having to drive whilst tired.

DRIVER SLEEPINESS AS A FACTOR IN CAR AND HGV ACCIDENTS

ABSTRACT

This report presents the results of two surveys - an interview survey of about 1000 HGV drivers and a postal questionnaire survey of just over 4600 male drivers aimed at exploring the relationship between accidents and daytime sleepiness. Drivers in this survey provided details of the accidents they had experienced in the last three years, and car drivers identified those factors they thought contributed to the accident. In addition to the normal demographic and exposure variables - age, annual mileage, and the proportion of time spent driving on different types of road - drivers completed the Epworth scale measuring daytime sleepiness; car drivers also reported whether they had felt close to falling asleep whilst driving during the past 12 months and whether the car they drove most was privately or company owned. In the case of car drivers, the analysis of this data has enabled the characteristics of tiredness-related accidents to be compared with the characteristics of all reported accidents. The probability of feeling close to falling asleep at the wheel has been quantified in terms of the demographic and exposure variables and Epworth score using a logistic model. Car drivers reported that about 7 per cent of accident involvements were associated with tiredness (about 9-10 per cent of accidents). The accident liability of both the HGV and the car drivers has been quantified using a multivariate statistical model; for some drivers accident liability is shown to be sensitive to daytime sleepiness.

1. GENERAL INTRODUCTION

Driver 'fatigue' is often cited as a cause of road accidents. In fact, fatigue is a condition which is not particularly well defined and may involve a variety of physiological and psychological states. Brown in his review of the subject, has defined fatigue as "a subjectively experienced disinclination to continue performing the task in hand" (Brown, 1994). Driving is a skilled task which is to a large extent self-paced. However, it is a task which requires sustained vigilance if accidents are to be avoided. Fatigue - for those drivers affected - is likely to result in impaired performance, resulting in an increase in the risk of becoming involved in an accident. Since the circumstances giving rise to fatigue and reactions to it will vary widely from person to person, it is likely that there will be large individual differences in both the experience of being fatigued and in the effect fatigue has on the individual driver's accident liability.

This report describes two surveys - the first an interview survey of male HGV (Heavy Goods Vehicle) drivers, and the second a postal questionnaire survey of male car drivers. The objectives of these two surveys are to obtain some basic information about the associations between sleepiness - as a key manifestation of fatigue - and accidents, and to quantify the extent to which these associations depend on individual and task related factors.

The report is structured as follows. Section 2 reviews the evidence available from other sources about the proportion of accidents in which fatigue or sleepiness may have been a contributory factor. Section 3 introduces the two surveys - in particular defining the Epworth daytime sleepiness scale which plays a significant part in both. The surveys themselves are then presented in sections 4 and 5, together with basic tabulations of accident data. Section 6 introduces a statistical model relating to car drivers, predicting the probability of falling asleep at the wheel, and section 7 presents statistical models for both HGV and car driver accidents, quantifying the effect of sleepiness (as measured by the Epworth scale) on accidents. Section 7 summarises the findings and draws conclusions. Appendices A to F deal with some detailed aspects of the surveys which it was considered inappropriate to include in the main report.

2. FATIGUE AS A CAUSE OF ACCIDENTS

2.1 GENERAL

On any particular journey, a driver may suffer from fatigue or sleepiness for a variety of reasons - some associated with the task of driving, others to do with more general lifestyle or health factors. Among the former would be the 'time on task' - the length of time the driver has been driving. Business and commercial drivers, particularly drivers of Heavy Goods Vehicles (HGV), often have to work prolonged and irregular hours and drive long distances every day. They may be under pressure to meet delivery deadlines despite difficult traffic situations. Associated with the amount of driving is the issue of *when* the driving is done; a driver may be excessively sleepy because he is driving at a time when he would normally be asleep - predominantly in the early hours of the morning and perhaps immediately after lunch - times when his circadian rhythms are out of step with the physical demands being placed upon him by the driving task.

More general lifestyle factors are also relevant. A driver may be sleepy because he has had insufficient sleep before commencing the journey. Indeed the effect of sleep deprivation may be cumulative, dependent on sleep patterns occurring over a significant period of time prior to the journey. A driver may be sleepy because he has a natural inclination to sleep during the daytime - he is a sufferer from excessive daytime sleepiness. There may also be medical causes of excessive daytime sleepiness, conditions such as sleep apnoea, though these are likely to be rare among a random sample of drivers.

A whole range of driving and non-driving related factors can affect an individual's propensity to experience sleepiness whilst driving, and can potentially increase the likelihood of that individual becoming involved in a sleep related accident. What evidence is there then, that being sleepy or fatigued whilst driving results in more accidents?

2.2 THE EVIDENCE FROM OTHER STUDIES

The contribution of fatigue to accident causation is difficult to establish, and studies which give reliable estimates (or indeed any estimates at all) are rare.

Storie (1984) studied 2000 HGV and PSV (Public Service Vehicles) accident involved drivers and found that 11 per cent of the accidents in which they were involved were due - at least in part - to fatigue. It is commonly assumed that fatigue is due mainly to driving long distances, but in Storie's account, over half the accident involved drivers had driven less than 100 miles before the accident. This confirms that fatigue arises not only from the time spent driving, but from many other factors outside the actual driving task which may result in daytime fatigue or 'sleepiness'. In a recent unpublished examination of fatal accident files involving HGVs, only 55 out of 1247 accident reports (4.4 per cent) mention fatigue as a possible contributory factor. By contrast publicity material circulated by the Road Safety Bureau of New South Wales, Australia, states that 'in-depth studies indicate that around 30 per cent of fatal heavy vehicle accidents involve fatigue'.

The same Road Safety Bureau material suggests that fatigue is implicated in 6 per cent of all accidents in New South Wales, and in 15 per cent of fatal accidents; the proportion rises to 30 per cent for fatal accidents in rural areas. A study of 204 fatal accidents on Bavarian highways (Zulley, Cronlein, Hell and Langweider, 1994) concludes that 24 per cent of these accidents were the result of falling asleep at the wheel. By contrast an American study (Pack, Cucchiara, Schwab, Rodgman and Pack, 1994) using data from North Carolina's crash reporting system (1990-1992), estimates that the proportion of crashes involving a driver who was judged to have fallen asleep at the wheel is only 0.46 per cent. Horne and Reyer (1995), report two studies of accidents to which the police were called, in which they identified sleep related accidents in circumstantial terms. Accidents were assumed to be sleep related if the vehicles involved had either run off the road or into the back of another vehicle in good visibility with no signs of the brakes being applied, if the police officers at the scene suspected sleepiness as the prime cause, and if vehicle defects, alcohol or speeding could be excluded as contributory factors. They found that sleep was likely to be a contributory factor in between 16 and 23 per cent of all accidents and that the number of sleep related accidents was higher during the night and in the mid-afternoon than at other times of day.

Although the identification of sleep related accidents is problematic, the brief review given above of evidence from 'in-depth' studies, suggests that sleep may be a factor in between 10 and 25 per cent of accidents, though the actual proportion will depend on a range of factors including type of road, time of day and severity of accident. Studies that used 'officially reported' accident data, seem to produce much lower estimates probably because accident-involved drivers are unlikely to admit to a police officer attending the accident that their driving was impaired prior to the accident combined with the fact that symptoms of sleepiness may not be evident to the police or to the witnesses involved. This provisional conclusion is borne out by the data to be presented in the next section.

2.3 EVIDENCE FROM POLICE DATA IN THE UK

In the 1950s the national system for recording injury accidents (STATS19) included data relating to an assessment of the factors judged by the police officer reporting the accident, to have contributed to its occurrence. The collection of this 'contributory factor' information was dropped from the national system some years later because it was perceived to be too subjective. However a number of police forces in the UK continued to collect contributory factor data for use by themselves and the Local Highway Authorities for the purpose of identifying accident problems for treatment. In the autumn of 1994 a survey of a number of police forces who still collected contributory factor data was undertaken to compare the coding systems in use, and to obtain views about the value of this data in identifying accident remedial measures.

Almost all forces who record contributory factors in accidents, have fatigue - sometimes combined with illness - as a factor. In most forces, the assignment of contributory factors is undertaken by the police officer who reports the accident. In some however, the coding is done by office staff basing their judgement on the brief accident report written by the police officer on the report form. On the grounds that the former assessment is likely to be the more reliable, Table 1 shows for those forces in which a police

TABLE 1

The percentage of accidents assessed by police officers as involving fatigue - by severity[1] and road type[2]

Police Force/County	Overall	By Severity F&S	By Severity SL	By Road Type HS	By Road Type LS
Devon	1.3	2.6	1.0	2.8	0.4
Cornwall	1.8	1.4	1.9	2.3	1.2
Wiltshire	3.7	4.5	3.5	5.3	1.9
Dorset	1.8	2.1	1.7	2.8	1.2
Durham	2.0	3.3	1.7	3.4	1.4
Leicestershire	1.7	2.4	1.6	3.9	0.6
Nottinghamshire	1.3	3.0	0.7	2.7	0.8
West Yorkshire	0.5	1.2	0.4	1.6	0.3
Hampshire	1.0	1.9	0.8	2.4	0.4

1 F&S - Fatal and serious, SL - Slight accidents
2 HS - High Speed Roads (Motorways, 70, 60 and 50 mph), LS - Low speed roads (30 and 40 mph)

officer codes the contributory factors directly, the proportion of accidents in which fatigue was judged to have been a contributory factor. The data refers to injury accidents (not accident involvements) in the whole of the relevant police force areas, and with the exception of Durham, is 1993 data; Durham only started recording contributory factor data in 1994, so the Durham entries in the Table refer to data collected in the first 10 months of 1994.

Table 1 shows that the proportion of accidents which in the judgement of the police have fatigue as a contributory factor ranges from 0.5 per cent in West Yorkshire to 3.7 per cent in Wiltshire. These figures are much lower than those resulting from 'in-depth' studies reported in the previous section, and much closer to the North Carolina study which itself was based on a national crash reporting system.

With the exception of Cornwall, Table 1 does however show that a higher proportion of the more serious accidents are consistently assessed by police officers as fatigue related, and a higher proportion still of accident on the higher speed roads are fatigue related. Both these findings are in agreement with the results of the studies reported in 2.2. Based on a simple average of the values in Table 1, fatal and serious accidents are 50 per cent more likely to involve fatigue, and accidents on high speed roads (motorways, 70, 60 and 50 mph speed limits) 80 per cent more likely to involve fatigue. The lower proportion of fatigue related accidents on low speed roads (30 and 40mph speed limits) probably goes some way to explaining the relatively low figure for the proportion of fatigue related accidents in the West Yorkshire conurbation.

It seems reasonable to conclude from these data, that the proportion of accidents involving fatigue as identified by police officers will be of the order of a few percent, and that this relatively low figure compared with other in-depth studies has to do with the difficulty anyone other perhaps than the individual driver has in assessing whether tiredness or sleepiness was a contributory factor in the accident. The remainder of this report will describe two surveys in which drivers have been asked to make their own assessment of tiredness as a contributory factor in the accident or accidents in which they have been involved.

3. INTRODUCING THE SURVEYS

3.1 SURVEY METHODOLOGY

In recent years a number of self-report surveys have been carried out to explore the relationship between the characteristics of individual drivers and their accident liabilities (see for example, Maycock, Lockwood and Lester, 1991, and Forsyth, Maycock and Sexton, 1994). Accident liability in this context is defined as the number of accidents an individual driver may be 'expected' to be involved in per unit time - expected that is, in a statistical sense; for example, the average accident liability for car drivers in the present study is 0.217 accident involvements in a 3-year period. The methodology has proved itself to be a reliable one for predicting associations between accident liability, demographic data (age, sex, driving experience), and exposure (annual mileage, frequency of trips). When therefore, planning a programme of research into sleepiness and driving, the method seemed to offer a powerful means of exploring the associations between individual driver characteristics (including sleepiness) and road accidents.

When comparing the results of surveys of the accident involvement rates of individual drivers with other studies, it is important to distinguish between accident rates - usually the number of accidents or a particular type per year - and accident involvement rates. Consider car accidents: if all car accidents involved two cars, then in a survey of the accident involvement of car drivers each driver would report the same accident as an 'involvement', and the accident involvement rate would be twice the accident rate. If on the other hand no car accidents involved another car - either because they were single vehicle accidents or accidents involving another type of road user - then each car driver involvement reported in the survey would correspond to an accident, and the car driver involvement rate would equal the accident rate. In reality for car drivers, the ratio of involvements to accidents will fall between these two extremes. In the national accident statistics (STATS19) relating to injury accidents, about one third of the accidents are car-car accidents, so that the ratio of involvements to accidents might be expected to be about 1.3-1.4. The proportion of HGV accidents involving 2 HGVs is on the other hand very small (3.4 per cent), so that HGVs involvement rates can be assumed to correspond to accident rates.

Two accident involvement surveys have been carried out - one of male Heavy Goods Vehicle (HGV) drivers, and the other of male car drivers. In the case of HGV drivers, for ease of sampling, an interview survey seemed appropriate. Approximately 1000 HGV drivers were interviewed at four motorway service stations during the last week in July 1993; this survey is described in section 4 below. For car drivers, the most appropriate technique was judged to be a postal questionnaire survey, and 9000 male car drivers sampled from the Driver and Vehicle Licensing Agency's (DVLA) driver file were surveyed in July/August 1994; this survey is described in section 5 below.

Both surveys were designed (among other things) to determine the relationship between accidents and daytime sleepiness. The 'objective' measure of an individual driver's propensity to fall asleep to be used in these surveys, was to be the Epworth daytime sleepiness scale. Since this scale is the key variable reflecting sleepiness in the analysis of accidents, it will now be defined.

3.2 THE EPWORTH SLEEPINESS SCALE

The Epworth Sleepiness Scale (ESS) has been developed to give a simple method of measuring the general level of daytime sleepiness in adults. It takes the form of a brief questionnaire which asks subjects to rate their chances, on a scale of 0-3, of dozing or falling asleep in 8 different situations. The situations are (i) sitting and reading, (ii) watching TV, (iii) sitting inactive in a public place, (iv) as a passenger in a vehicle, (v) lying down to rest in the afternoon, (vi) sitting and talking to someone, (vii) sitting quietly after lunch and (viii) in a vehicle while stopped for a few minutes in traffic. The scale as administered to the HGV drivers together with the interviewers instructions is given in Appendix A; a corresponding self completion scale was included in the car drivers questionnaire. The total score from the scale will range from 0-24.

Johns found that the ESS is reasonably reliable under test-retest conditions, and has a high level of internal consistency (Johns, 1992). The score obtained using the ESS may, therefore, be assumed to be a fairly reliable indicator of daytime sleepiness. Johns (1991) reported that scores of 16 or more, which indicate a high level of daytime sleepiness, were found in patients with medical conditions such as narcolepsy or obstructive sleep apnoea. Sleep apnoea is characterised by frequent pauses in breathing during sleep, leading to loud snoring during the night, and extreme sleepiness during the day.

Figure 1 shows the distribution of the Epworth scale scores for the respondents in both surveys.

The figure shows that the Epworth score distribution is very similar for HGV and car drivers. The mean value of the Epworth score for HGV drivers is 5.7 compared to 6.2 for car drivers. The distribution is asymmetrical with the bulk of drivers scoring between 3 and 7, but with a noticeable upper tail. However, only about 0.3 per cent of HGV drivers and 0.8 per cent of car drivers have an Epworth score of more than 16, thus falling into the category of people who according to Johns' criterion, could be suffering from sleep apnoea. In view of this, it seems unlikely that the consequences of sleep apnoea will be a major contributory factor in the accidents experienced by the drivers in these surveys.

4. THE HGV DRIVER INTERVIEW SURVEY

4.1 THE SAMPLE

Approximately 1000 male Heavy Goods Vehicle (HGV) drivers were interviewed at four motorway service stations: Membury on the M4, Fleet on the M3, Trowell on the M1, and Charnock Richard on the M6. About 250 subjects were interviewed between the hours of 8am and 5pm at each service area during the last week in July 1993. At each location, drivers were sampled equally between the two carriageways in order to get as representative a sample of drivers as possible. During each session of interviewing, drivers were chosen randomly according to who was available at the time the previous interview finished. The interviews were carried out by a team of experienced TRL interviewers who used a printed questionnaire with cue cards as aids to asking certain questions and recording the answers.

The analyses given in this report are based on the 996 completed questionnaires which resulted from these interviews. Not every question was answered, so that in general

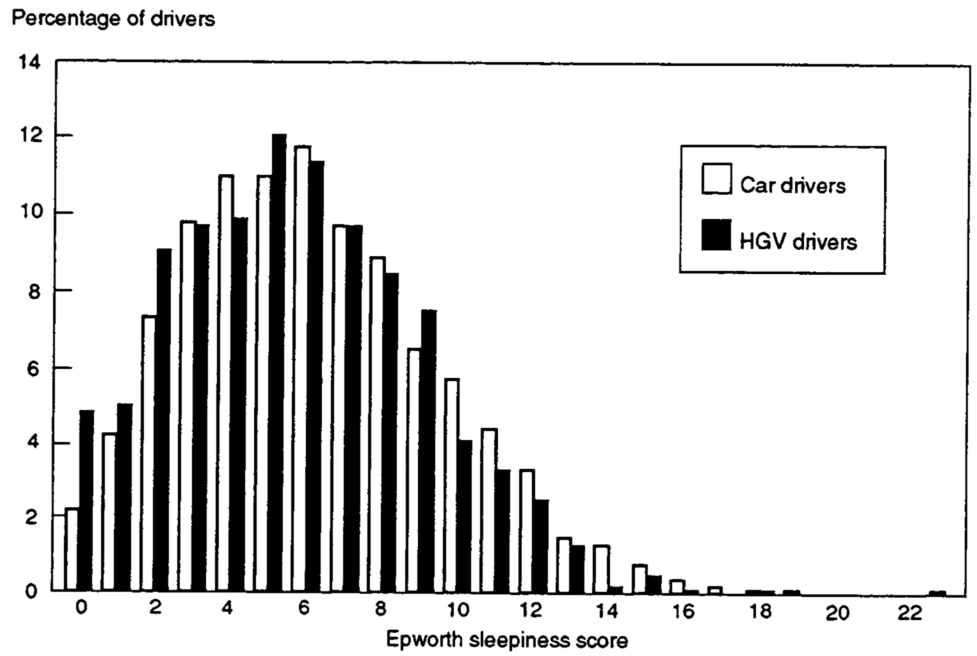

Fig. 1 Distribution of Epworth daytime sleepiness scores

tabulations will have some missing data. The number of valid responses available when compiling each table is shown where appropriate.

4.2 THE QUESTIONNAIRE

The questionnaire used in the study consisted of 4 parts. Part 1 asked about the mileage the drivers had travelled in the previous year, and how much driving time was spent on British and foreign motorways.

An attempt was then made in Part 2 to determine the drivers' activities during 'typical' week-day and Saturday. However, obtaining and coding this information in a consistent way did not prove easy and since the data collected did not prove useful in explaining the between driver differences in accidents these results are not discussed further in this report.

In Part 3 of the questionnaire, drivers were asked to report how many accidents they had been involved in during the last **three years.** If they had been accident involved, they were asked to provide information about their accidents. Information was collected about the severity of each accident, what other vehicles, road users, or objects were involved, the type of road on which the accident occurred, the date of the accident and the length of time the driver had been driving during the particular journey prior to the occurrence of the accident.

In Part 4 of the questionnaire drivers were also asked how old they were and how long they had been driving an HGV. This part of the questionnaire also included the Epworth Sleepiness Scale, and in view of the possible connection between night-time sleep impairment and snoring (see 3.2 above) drivers were asked to say whether they snored at night on a 4-point scale (not at all, rarely, occasionally or every night). The interviewers also recorded some indicators of possible physical characteristics which might be indicative of night-time sleep problems. Medical evidence suggests that there are certain physical factors which can for some individuals result in impaired breathing during night-time sleep, resulting in excessive daytime sleepiness. In extreme cases the individual may be suffering from obstructive sleep apnoea (see 3.2 above) - a condition exacerbated by obesity, especially a fat neck - i.e. a large collar size - and/or obstructed airways evidenced by a nasal sounding voice. For these reasons the interviewers were asked to record whether or not in their judgement the driver was 'obese', whether or not he had a noticeably large collar size, and whether or not the driver spoke 'nasally'. The definitions of these terms were discussed during the briefing of the interviewers to obtain some consistency of definition, but in the end, the decision was a matter of the interviewer's subjective judgement.

4.3 CHARACTERISTICS OF THE HGV DRIVER SAMPLE

The frequency distributions of drivers included in the sample by age, driving experience and annual mileage are tabulated in Appendix B. Driver's ages were fairly evenly spread over the 20 - 60 age range; the mean age was 41 years. A wide range of driving experience was also represented in the sample; the mean length of time drivers had been driving an HGV was 18 years. The correlation matrix shown in Appendix B shows that age and driving experience were highly correlated (correlation coefficient 0.86) - a fact which means that either age or driving experience, but not both, can be used as an explanatory variable in the multivariate accident modelling to be described in section 7.

Annual mileages reported by the HGV drivers ranged from 4000 to an improbable 275,000 with a mean of 69,700; the distribution is fairly uniform between 40,000 and 100,000 miles. Annual mileage is very difficult to estimate, particularly for drivers who cover very high mileages. It is perhaps fortunate therefore - as the subsequent analysis will show - that for high mileage drivers, the expected number of accidents in which a driver is likely to become involved, is almost independent of annual mileage.

The HGV drivers interviewed spent an average of 67 per cent of their driving time on motorways. The distribution was skewed towards the upper end such that about a third of drivers spent over 80 per cent of their driving time on motorways. The motorway driving of most of the drivers interviewed (87 per cent) was solely on motorways in the UK.

4.4 HGV DRIVER ACCIDENTS

4.4.1 Accident types and locations

Drivers were asked to report all accidents they had experienced in the last three years. In the main therefore, these accidents involved damage only. Of the 996 HGV drivers included in the analysis, 205 reported having been involved in an accident in the last three years. These 205 drivers reported 252 accidents of which 83.6 per cent did not involve injury, 10.4 per cent involved a slight injury, 4.4 per cent a serious injury and 1.6 per cent a fatality (not of course, the driver). Despite the small numbers of injury accidents involved in this survey, the ratios of fatal, serious and slight accidents obtained are not inconsistent with the accident involvement rates reported in the national accident statistics (STATS19) for HGVs. 16.4 per cent of the accidents occurred on a motorway and the remainder on all-purpose roads.

Table 2 shows the proportion of accidents involving other vehicles or road users. It will be seen that 70 per cent of the HGV accidents involved another moving vehicle and about 17 per cent involved a stationary vehicle. The distribution of accident types reported by drivers in the survey did not depend on their age.

4.4.2 Accident involvement frequencies: exposure and age

The tables in this and the following sections present average self-reported accident involvement frequencies (the average number of accidents reported during the 3-year recall period) classified by the variables on which these accidents might be expected to be dependent. In each case

TABLE 2

HGV accident types

Type of vehicle involved	Number of accidents	%
Moving vehicle	171	70.1
Stationary vehicle	42	17.2
Parked vehicle	1	0.4
Cyclist/Motorcyclist	5	1.6
Other	6	10.7
Total	225	100

the frequencies presented are simple averages and take no account of inter-correlations between the variables.

Table 3 shows the mean accident involvement frequency (3 year period) for HGV drivers as a function of annual mileage.

The table shows that with the exception of group 4 (80,000 - 99,999 miles) the involvement frequencies are very similar ranging from 0.23 to 0.25 accidents in 3 years. Group 4 drivers have a rather higher value (0.39), though with 95 per cent confidence intervals as high as ±0.12 even this high figure can hardly be considered remarkable. The absence of any indication that accident rates increase significantly with mileage is confirmed by the multivariate modelling (see Section 7), in which annual mileage did not prove to be a significant predictor of accidents.

The absence of a mileage effect is at first sight surprising. However, studies of the accident liability of car drivers (e.g. Maycock and Lockwood, 1991 and Kompfner and Divey, 1992) showed that the accident - mileage relationship flattens off at high mileages. For HGV drivers who cover very high mileages each year, this flattening off effect would seem to be almost total; their accidents do not increase with mileage at all and their accident rates per mile (or per million vehicle miles) are thus inversely proportional to mileage. No satisfactory explanation has yet been given for this effect.

Table 4 shows the effect of age on average accident involvement frequency; the ages of drivers have been grouped to give between 100, and 200 drivers in each group. Analysis of variance shows this to be a very significant effect; it is also significant in the multivariate modelling. The average number of accidents per 3 years fall from 0.44 for the 17 - 29 age group to less than one third of that figure for the over 55s. Of course, since age and driving experience (the length of time the driver has been driving an HGV) are very highly correlated in this sample, the result shown in Table 4 really illustrates the combined effects of age and driving experience on accidents.

TABLE 3

HGV driver accident involvement frequencies as a function of annual mileage (grouped)

Mileage Groups	Number of drivers	Average accidents per 3 years	Standard errors
Up to 39,999	137	0.23	0.05
40,000 - 59,999	264	0.23	0.03
60,000 - 79,999	269	0.25	0.03
80,000 - 99,999	127	0.39	0.06
100,000 and over	193	0.24	0.04
Total	990	0.26	0.02

TABLE 4

The effect of the HGV driver's age (in combination with driving experience) on accident involvement frequency

Age Groups	Number of drivers	Average accidents per 3 years	Standard errors
17 - 29	154	0.44	0.06
30 - 34	144	0.40	0.06
35 - 39	139	0.27	0.04
40 - 44	132	0.17	0.04
45 - 49	172	0.15	0.03
50 - 54	134	0.17	0.04
55 and over	117	0.14	0.04
Total	992	0.25	0.02

4.4.3 Accident involvement frequencies: The Epworth Sleepiness Scale

Table 5 shows the average accident frequencies for drivers grouped by their score on the Epworth sleepiness scale.

It will be seen that although there is a trend for increasing accident involvements for those scoring 2 or more on the Epworth scale, the average for drivers scoring 0 or 1 is higher than for drivers scoring 6 or over. The fact is, that the standard errors of these grouped accident rates are such that no reliable effects can be discerned from overall averages. The effect of daytime sleepiness will only emerge from the analysis once other correlated variables have been taken into account using a multivariate method.

4.4.4 Accident frequencies: snoring

Because of the potential link between night-time sleep deprivation and snoring mentioned in 3.2 and 4.2 above, HGV drivers were asked to say whether they snored when asleep at night. Few drivers were unable to answer, and two

TABLE 5

The score on the Epworth daytime sleepiness scale in relation to the accident involvement frequencies of HGV drivers.

ESS Scores	Number of drivers	Average accidents per 3 years	Standard error
0 and 1	98	0.29	0.05
2 and 3	186	0.20	0.03
4 and 5	218	0.23	0.04
6 and over	489	0.27	0.03
Total	991	0.25	0.02

thirds of those responding to this question said that they snored. When asked whether they snored 'every night', 'occasionally' or 'rarely', the responses given in Table 6 were obtained. Table 6 also shows the average accident frequency for these three groups compared with the one third of drivers who did not snore.

As will be seen from the table, there is little difference between the accident liabilities of three groups who do not snore every night, but those who do, appear to have an enhanced accident expectation.

4.4.5 Accident frequencies: physical factors

Because of the possible association referred to in sections 3.2 and 4.2 above between potential night-time sleep impairment and obesity, neck (collar) size and nasal airway obstruction, interviewers recorded their judgements as yes/no responses to the following questions:

Is the driver obese?

Does the driver have a noticeable large collar size?

Does the driver speak nasally?

Table 7 shows the proportion of drivers falling into each category, together with the average accident frequencies in each case. Analysis of variance shows the differences in the accident frequencies for both obesity and collar size to be statistically significant at the 5 per cent level or better - collar size giving a higher variance ratio (F = 4.6) possibly because of the larger proportion of drivers classified 'Yes'. Drivers characterised as speaking nasally were only 10 per cent of the total, and the accident frequency difference in this case, though very similar in magnitude to both obesity and collar size, did not prove to be statistically significant even at the 10 per cent level.

The accident involvement frequencies of HGV drivers in relation to the variables included in sections 4.4.2 to 4.4.5 will be taken up again in section 7 below in which the multivariate modelling of the data is described.

5. THE CAR DRIVER POSTAL QUESTIONNAIRE SURVEY

5.1 THE SAMPLE

In order to obtain detailed accident and exposure data for this study, 9000 male car drivers were sent a postal questionnaire. The drivers were selected at random from the Driver and Vehicle Licensing Agency database of current

TABLE 6

Snoring in relation to the accident involvement frequencies of HGV drivers.

Frequency of snoring	Number of drivers	Average accidents per 3 years	Standard errors
Not at all	317	0.24	0.03
Rarely	57	0.23	0.08
Occasionally	345	0.24	0.03
Every night	235	0.31	0.04
Total	954	0.26	0.02

TABLE 7

Accident involvement frequencies of HGV drivers with physical characteristics which could be related to sleep apnoea.

	Number of drivers	% responding		Average accident frequencies	
				Mean	S.E.
Is driver obese	987	Yes	12.7	0.34	0.06
		No	87.3	0.24	0.02
Large collar size	986	Yes	18.2	0.34	0.05
		No	81.8	0.24	0.02
Speaks nasally	984	Yes	10.1	0.32	0.06
		No	89.9	0.25	0.02

licence holders stratified into six age bands: 17-24, 25-34, 35-44, 45-54, 55-64, and 65 and over. The questionnaires were sent out between July and August 1994. After non-valid questionnaires had been eliminated, 4621 questionnaires were available for analysis. Not every question in these questionnaires had been answered, so that in general the tabulations given later in this report will have some missing data. The number of valid responses used when compiling each table is shown as appropriate.

5.2 THE QUESTIONNAIRE

The questionnaire used in the study consisted of four sections. Section 1 asked for estimates of the number of miles the respondent had driven in the previous year, the proportion of driving time he had spent on three categories of road - motorways, roads in built up areas and road outside built up areas, and the frequency of driving - everyday, 5/6 days a week and so on. Because company car drivers drive larger distances than private car drivers - a higher proportion of which is on motorways - and since it seemed likely that company car drivers would be more likely to be driving during 'unsocial' hours under pressures of time - it seemed possible that company car drivers would be more vulnerable than private car drivers to the effects of tiredness. Drivers were therefore asked whether most of the driver's mileage had been in a private or a company car. In the later analysis this factor is a 2-level factor called 'CAR' which is coded 1 for drivers who use a private car mostly, and 2 for those using company cars mostly. Respondents were not given a precise definition of a company car, so that the company car category will include a number of different groups driving company funded cars.

Section 2 contained questions about driver's accident involvement. The drivers were asked to report the number and severity of the accidents in which they had been involved in the last three years - as for the HGV drivers. For each accident, they were asked to report whether the accident occurred in daylight or darkness, the type of road on which the accident happened, whether it was wet or dry at the time, and what other vehicle, road user or object was involved in the accident. They were also asked to give an opinion about those factors which had influenced their own role in the accident.

Section 3 asked questions about the incidence of sleepiness while driving, including how many hours they would drive on a long journey before taking a break. Information was also elicited about the measures drivers had found helpful to counter sleepiness whilst driving. In particular, this section asked drivers whether in the last 12 months they had felt close to falling asleep at the wheel. For use in the subsequent analysis, the driver's response to this question was coded by means of a factor called 'SLEEPY' - 1 for drivers who had not felt close to falling asleep and 2 for those that had. This part of the questionnaire also included the Epworth Sleepiness Scale.

Section 4 of the questionnaire asked for drivers' personal details, such as height, weight, age, collar size and occupation. As in the case of the interview study of HGV drivers, the physical characteristics were obtained because of the potential link between these characteristics and night-time sleep impairment.

5.3 CHARACTERISTICS OF THE CAR DRIVER SAMPLE

5.3.1 Frequency distributions

The frequency distributions of car drivers included in the sample by age, occupational group, annual mileage, and amount of driving by road type are tabulated in Appendix C. To provide some insight into the differences between private and company car drivers and into the effect of sleepiness, the tables both in Appendix C and in section 5.4 below have been disaggregated into 4 groups by the two factors CAR and SLEEPY defined in the previous section. The relevant aspects of these distributions are summarised in the following paragraphs.

5.3.2 Age and occupational group

The average age of the drivers in the survey was 48. Although the sampling method was designed to ensure a fairly even spread of ages, the poorer response rate from the younger drivers resulted in a sample which was somewhat biassed towards the older drivers. Not surprisingly, most of the over 65 year old drivers drive private rather than company cars. Rather more surprising is the fact that the proportion of drivers who have been close to falling asleep at the wheel declines for the older age groups. It would appear that although older drivers are slightly more likely to suffer from daytime sleepiness than younger drivers (correlation coefficient 0.06 - see Appendix C), they do not drive as far each year as do the younger drivers, and probably do not need to drive at times when they would be at risk of falling asleep at the wheel.

The occupational groups used in the survey were as follows:

- A/B Senior managerial, administrative or professional,
- C1 Junior managerial, administrative or professional,
- C2 Skilled manual,
- D Semi-skilled and unskilled manual,
- O Student, housewife/husband, retired or unemployed.

There were about 20 per cent of drivers in each of the first three groups, 10 per cent in group D and the remainder (30 per cent) in group O. Not surprisingly, a far higher proportion of company car drivers than private car drivers were in the senior managerial, administrative or professional group

(A/B), a group which also includes a higher proportion of drivers who have felt close to falling asleep at the wheel (SLEEPY=2).

5.3.3 Exposure factors

The average annual mileage for drivers in the sample was 11,380. Not surprisingly, there are marked differences in annual mileage between those driving private cars and those driving company cars (Appendix C). Over 60 per cent of the private car drivers who *had not* felt close to falling asleep at the wheel drive less than 10,000 miles per year. At the other end of the spectrum, nearly 60 per cent of company car drivers who *had* felt close to falling asleep at the wheel, cover more than 20,000 miles annually. It seems likely that annual mileage, combined with the times of day when this mileage is driven, is very influential in determining whether or not a driver is likely to have felt close to falling asleep at the wheel during the last 12 months. Estimates of average annual mileages by age show that generally, annual mileage reaches a maximum in the middle years (35-55) with both younger and older drivers driving fewer miles annually. Company car drivers who have felt close to falling asleep at the wheel appear to be an exception to this rule; in this category, the highest mileage drivers are those in the youngest age group.

The frequency of trip making (that is, whether the respondent drivers every day, or less often) reflect the estimated annual mileage. It is a measure which is not of any great interest in its own right, but is useful in modelling exposure to risk of an accident in the modelling process (see section 7). Appendix C contains a Table showing the amount of time drivers spend on three types of road - motorways, roads not in built-up areas and roads in built-up areas. The proportion of mileage driven on rural roads is roughly constant irrespective of mileage; respondents who drive high mileages spend relatively more of their driving time on motorways at the expense of driving on roads in built-up areas. These road type effects do not prove to be directly useful in modelling accident liability, but are significant predictors of the probability of falling asleep at the wheel which itself is a significant predictor of accidents.

5.3.4 Epworth score (ESS)

Figure 1 has illustrated the overall distribution of the Epworth daytime sleepiness scores (ESS) among the car drivers in this sample. The distribution of Epworth scores among drivers grouped by the factors CAR (private or company car) and SLEEPY (whether or not the driver has been close to falling asleep at the wheel in the past 12 months), shows that drivers who had felt close to falling asleep at the wheel had, not surprisingly, higher daytime sleepiness scores (average ESS=7.2) than those who had not felt close to falling asleep at the wheel (average ESS=5.8). More surprising is the fact that the company car drivers appear to have rather lower average Epworth scores than the private car drivers. In fact, the difference between company and private car drivers is statistically significant at the 5 per cent level only for the group who had not felt close to falling asleep at the wheel; the average Epworth score for private car drivers in this case was 5.9, compared with 5.3 for company car drivers. This difference may well be due in part at least, to the fact that the private car drivers are on average rather older than the company car drivers.

5.4 CAR DRIVER ACCIDENTS

5.4.1 Accident types, locations and times of day

Of the 4621 drivers who responded to this survey, 3794 (82.1 per cent) reported having been accident free in the last 3 years, 680 (14.7 per cent) had been involved in 1 accident, 125 (2.7 per cent) in 2 accidents, 19 (0.4 per cent) in 3 accidents; 1 driver reported 4 accidents, 1 driver 5 accidents and one driver reported 7 accidents in the 3 year period. The total number of accidents reported is thus 1003 representing an average frequency of 0.217 accidents in the 3 year period. Drivers reported that 125 (12.5 per cent) of these accidents involved injury.

Drivers were asked to provide detailed information about the first three accidents they had experienced in the last three years. The following tables are therefore based on a maximum of 996 accidents of all kinds including a maximum of 125 injury accidents; the actual numbers in the tables will in most cases be somewhat less than this due to respondents not always providing the relevant information for cross-tabulations.

Table 8 shows that in the case of all accidents, over two thirds involved the respondent's car hitting another moving vehicle, and a stationary vehicle was involved in a further 18 per cent of these accidents - figures very similar to the

TABLE 8

Objects involved in the accidents reported by car drivers

Objects involved other than the driver's own car	Percentage of accidents	
	All accidents	Injury
Moving vehicles	68.8 %	72.6 %
Stationary vehicles	18.4 %	10.5 %
Road furniture	5.7 %	6.5 %
Kerbs or islands	5.6 %	3.2 %
Nothing	4.0 %	2.4 %
Animals	1.9 %	1.6 %
Pedestrians	1.6 %	10.5 %
Trees	1.6 %	5.6 %
Other objects	1.6 %	2.4 %
Cyclists	0.9 %	4.8 %

characteristics of the HGV accidents. In just over 11 per cent of accidents the respondents car hit some part of the immediate road environment (road furniture, kerbs or islands), and in 4 per cent of accidents the driver went off the road without hitting anything.

With the possible exception of pedestrians and cyclists (and trees?), the pattern of objects involved in injury accidents is similar to 'all' reported accidents which are mostly damage only. The proportion of injury accidents involving vulnerable road users is noticeably higher than for 'all' accidents. Obviously by definition, accidents involving 'vulnerable' road users are more likely to be injury accidents.

6.3 per cent of accident involvements occurred on motorways, 28.5 per cent on rural roads (not in built-up areas) and 65.2 per cent on roads in built up areas. The corresponding figures for the *injury* accident involvements reported in this survey are 7.3 per cent, 36.6 per cent and 56.1 per cent respectively on the three types of road. The fact that drivers estimate they spend 21.6 per cent of their time driving on motorways, 31.7 per cent on non-built-up roads and 46.6 per cent on built-up roads, highlights the relatively safe performance of motorways per mile driven, compared with roads in built-up areas.

Table 9 shows the distribution of accident involvements by time of day. The distribution for 'all' accidents reported in this survey is similar to that for injury accidents, and both are similar to the distribution of injury accidents by time of day reported in Road Accidents in Great Britain (1993).

TABLE 9

Percentage of car driver accident involvements by time of day

Time of Day	Percentage of accidents	
	All	Injury
Midnight - 4 am	2.5 %	4.4 %
4 am - 8 am	6.2 %	4.3 %
8 am - Midday	25.9 %	23.9 %
Midday - 4 pm	28.2 %	22.2 %
4 pm - 8 pm	28.2 %	32.4 %
8 pm - Midnight	9.0 %	12.9 %

5.4.2 CONTRIBUTORY FACTORS IN THE ACCIDENTS

Survey respondents were asked to identify as objectively as they were able, the factors which had influenced *their role* in the accident. A list of possible accident contributory factors was offered in the questionnaire, with an open ended question providing the opportunity to supply any additional factors. Tables 10-12 shows the 9 most frequently identified factors cross-tabulated by road type, age, and time of day respectively. The minority categories provided in the questionnaire but not listed in the tables are poor signing (2 per cent), vehicle faults - e.g. tyres or brakes (2 per cent), inappropriate overtaking (1 per cent) and alcohol/medical impairment (<1 per cent).

Column 2 of Table 10 shows the overall percentage of all accidents which had involved each contributory factor; since more than one factor could be chosen for a given accident, the column adds up to more than 100 per cent. It will also be seen from the table that overall, 43 per cent of accident involvements did not have one of the factors listed in the questionnaire assigned; this is mainly because in those accidents in which drivers felt themselves to be the 'innocent' party, no response was offered to this question.

It will been seen from the overall figures in Table 10 that the four most frequently cited contributory factors are inattention or distraction, misjudgment, problems of visibility and driving too fast. Tiredness as a contributory factor ranks fifth, with 7 per cent of accident involvements having this factor ascribed to them. It is important to remember that the tables record the proportion of accident involvements and not the proportion of accidents. As pointed out in 3.1 above, the majority of accidents will involve more than one vehicle. If it is assumed that in the case of most car-car accidents, one of the drivers is to blame and the other 'innocent', it follows that to convert from the proportion of accident involvements to the proportion of accidents, requires the former to be multiplied by the number of car involvements per accident. Although accurate figures are not available for this particular data set - and indeed the figure would vary with road type, time of day, and other factors - a reasonable value would be the 1.3-1.4 suggested in 3.1 based on STATS19 data. Thus the 7 per cent of accident involvements reported by drivers in this survey as being tiredness related, probably means that between 9 and 10 per cent of accidents are tiredness related. In relation to accidents, a similar adjustment would have to be made to all the figures given in Tables 10-12.

Columns 3-5 of Table 10 show the way the proportion of contributory factors depend on road type. The final column indicates whether or not the differences observed between the columns in the Table are statistically significant on the basis of a simple χ^2 test in which the expected number of factors are proportional to the number of accident involvements in each category.

Whereas the proportion of accident involvements arising from inattention, misjudgment or problems of visibility do not differ significantly between the three road categories, tiredness as a factor varies in a consistent way. On motorways, tiredness was cited as a contributory factor in 15 per

TABLE 10

Self assigned contributory factors in car driver accident involvements - overall and by type of road

Contributory factors	Overall	Motorway	Non Built-up areas	Built-up areas	Significance[1]
			(Percentage of accident involvements)		
Inattention/distraction	24	18	21	26	-
Misjudgment	15	16	12	16	-
Visibility problem (eg dazzle, obscuration)	11	3	10	11	-
Driving too fast	8	11	13	5	***
Tiredness	7	15	10	5	***
Driving too close	7	13	4	7	**
Road surface fault	6	7	10	4	***
Road layout fault	5	2	7	5	-
Lack of skill/inexperience	5	2	9	4	***
Other/missing	43	38	39	45	
Number of accidents	965	61	275	629	

1 Asterisks indicate whether the numbers of factors differ significantly between columns.
*** significant at the 1 per cent level: ** 5 per cent level: * 10 per cent level.

TABLE 11

Self assigned contributory factors in car driver accident involvements by age group

Contributory factors	17-24	25-34	35-44	45-54	55-64	65 and over	Significance[1]
					(Percentage of accident involvements)		
Inattention/distraction	27	21	27	21	24	21	-
Misjudgment	18	14	14	14	14	8	-
Visibility problem (eg dazzle, obscuration)	11	14	8	8	15	5	**
Driving too fast	11	9	12	6	5	1	***
Tiredness	9	6	12	6	3	2	***
Driving too close	9	8	8	6	2	3	*
Road surface fault	4	7	7	5	6	4	-
Road layout fault	7	5	4	3	8	2	*
Lack of skill/inexperience	15	3	3	2	-	-	***
Other/missing	17	44	35	51	44	57	
Number of accidents	224	168	170	174	133	115	

1 See footnote to Table 10

cent of accident involvements (20 per cent of accidents on motorways), a figure which falls to 10 per cent on rural roads (14 per cent of accidents) and to 5 per cent in built-up areas (7 per cent of accidents). This result confirms the expectation that motorway driving, often involving monotonous long-distance journeys, is likely to result in a higher proportion of sleep related accidents. It is also of interest to note that driving too fast follows a similar pattern. The proportion of tiredness related accidents on rural roads and motorways (corresponding roughly to the 'high speed' roads of Table 1) is thus, according to respondents in this survey, somewhat more than twice the

TABLE 12

Self assigned contributory factors in car driver accident involvements by time of day

Contributory factors	Hours beginning:						Significance[1]
	0-3	4-7	8-11	12-15	16-19	20-23	
					(Percentage of accident involvements)		
Inattention/distraction	18	16	27	27	22	20	-
Misjudgment	9	18	14	18	14	11	-
Visibility problem (eg dazzle, obscuration)	5	11	11	10	12	12	-
Driving too fast	18	14	6	9	6	15	**
Tiredness	27	14	3	6	8	10	***
Driving too close	-	7	6	8	9	2	-
Road surface fault	9	16	8	4	3	9	***
Road layout fault	9	-	4	4	7	9	-
Lack of skill/inexperience	5	4	4	4	6	5	-
Other/missing	50	36	41	40	45	48	
Number of accidents	22	56	232	253	253	81	

1 See footnote to Table 10

proportion on built-up roads ('low speed' roads - Table 1) - a figure which, given the differences in road type definitions, is not inconsistent with the factor of 1.8 obtained from police data.

Table 11 shows the breakdown of contributory factors by age group. Once again inattention and misjudgment as factors in accidents do not seem to be age dependent. Tiredness, though fairly evenly spread among the younger drivers, diminishes significantly for the older age groups, probably reflecting their more judicious approach to driving long distances during unsocial hours. Again, driving too fast follows a similar pattern.

Table 12 shows the time of day effect. The hours of the day are grouped into 6 4-hour periods starting at midnight. Once again the three most frequently mentioned accident causes are not dependent on time day. However, the table shows the consistent and expected pattern of accidents involving tiredness. In the early hours of the morning, tiredness is reported as a factor in 27 per cent of the accident involvements (36 per cent of the accidents) - a proportion which declines to a minimum of 3 percent of involvements (4 per cent of accidents) during the morning, rising again through the afternoon and evening. Interestingly, speed again follows the same pattern. In the late evening and early hours of the morning, when traffic flows are light, and speeds are high, driving too fast becomes an increasingly significant factor in accidents; it is these very same times of day, that drivers are at their most vulnerable to accidents as a result of tiredness.

5.4.3 Accident involvement frequencies: exposure and age

Table 13 shows the effect of age on reported accident involvement frequencies (accident involvements in 3 years). Frequencies are given in the Table for the four groups of drivers defined by the factors SLEEPY and CAR. It will be seen that involvement frequencies fall considerably with increasing age, and that drivers who have felt close to falling asleep at the wheel in the past 12 months (SLEEPY=2) have higher involvement frequencies than those who have not (SLEEPY=1). The Table also shows that company car drivers (CAR=2) have higher accident involvement frequencies than those driving private cars (CAR=1).

In Table 13 and those that follow, the number of accidents contributing to the mean accident frequencies, is given in the Tables in italics. This enables the 95 per cent confidence limits of the estimate of the mean frequency to be calculated: it is approximately $2x[\text{mean accident frequency}/\text{number of accidents}]^{0.5}$.

Table 14 shows how accident involvement frequencies increase with annual mileage for the four groups of drivers defined by SLEEPY and CAR. Again the differences between the four groups are clearly evident. It is also clear that, as in most other studies of accident liability, the accident frequencies are not proportional to annual mileage. Consider for example, the total column in Table 14. Whereas from the lowest to the highest mileage band, the annual mileage increases by a factor of about 18 (based on

TABLE 13

Accident involvement frequency by age and by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.

(Number of accidents in italics)

Age band	SLEEPY=1				SLEEPY=2					
	Private Car		Company Car		Private Car		Company Car		Total	
17-24 years	0.324	*337*	0.465	*43*	0.473	*169*	0.500	*28*	0.385	*582*
25-34 years	0.205	*308*	0.329	*73*	0.287	*185*	0.368	*76*	0.259	*648*
35-44 years	0.176	*370*	0.205	*78*	0.303	*162*	0.374	*115*	0.237	*735*
45-54 years	0.154	*422*	0.196	*102*	0.240	*175*	0.369	*130*	0.211	*841*
55-64 years	0.131	*557*	0.200	*80*	0.189	*143*	0.255	*51*	0.157	*850*
65 years and over	0.123	*790*	0.091	*11*	0.188	*85*	0	*1*	0.127	*905*
Overall average	0.170	*2784*	0.251	*387*	0.291	*919*	0.364	*401*	0.217	*4561*

TABLE 14

Accident involvement frequency by annual mileage and by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.

(Number of accidents in italics)

Annual mileage band	SLEEPY=1				SLEEPY=2					
	Private Car		Company Car		Private Car		Company Car		Total	
Less than 5,000	0.116	*769*	0.952	*42*	0.146	*103*	0.333	*12*	0.120	*951*
5,000-10,000	0.168	*975*	0.107	*56*	0.199	*221*	0.286	*28*	0.175	*1299*
10,000-15,000	0.200	*696*	0.284	*74*	0.308	*318*	0.182	*66*	0.232	*1171*
15,000-20,000	0.230	*183*	0.229	*70*	0.300	*140*	0.259	*54*	0.254	*452*
20,000-30,000	0.181	*127*	0.329	*76*	0.443	*97*	0.462	*117*	0.344	*421*
Over 30,000	0.372	*43*	0.403	*67*	0.535	*43*	0.446	*121*	0.435	*276*
Overall average	0.169	*2793*	0.257	*385*	0.287	*922*	0.367	*398*	0.217	*4570*

group averages of 2,262 and 40,634 miles respectively), the involvement frequencies increase by only a factor of 3.6.

5.4.4 Accident involvement frequencies: The Epworth Sleepiness Scale

Table 15 shows the 3-year accident involvement frequencies tabulated in terms of a grouped version of respondents' Epworth Sleepiness score - again for the four groups of drivers defined by SLEEPY and CAR.

From the final column of Table 15 it will be seen that in aggregate, there is only a slight indication that accident frequencies increase with Epworth score. However, the increase for company car drivers (CAR=2) is much more pronounced - particularly for company car drivers who have felt close to falling asleep at the wheel in the last 12 months (CAR=2, SLEEPY=2). It is also noticeable that for private car drivers who have not felt close to falling asleep at the wheel (CAR=1, SLEEPY=1), the effect is negative - higher Epworth scores correspond to lower accident frequencies. These interactive effects will be quantified in the accident modelling (Section 7), taking into account the differences in age and annual mileage of drivers in the four groups.

5.4.5 Accident involvement frequencies: snoring

It will be recalled that from the physiological point of view snoring at night may be an indicator of impaired night-time sleep which could have adverse consequences in terms of excessive daytime sleepiness. Table 16 shows the effect on accident involvement frequencies of whether a driver snores every night or not. In the questionnaire responses, four categories of snoring were identified: (i) does not snore, (ii) snores sometimes, (iii) snores frequently and (iv) snores every night. As in the case of the HGV drivers (Table 6), there was no statistical difference between categories (i), (ii) and (iii). Table 16 therefore shows the difference

TABLE 15

Accident involvement frequency by Epworth Sleepiness Score and by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.
(Number of accidents in italics)

Epworth Score band	SLEEPY=1				SLEEPY=2					
	Private Car		Company Car		Private Car		Company Car		Total	
Less than 3	0.203	*637*	0.175	*114*	0.267	*146*	0.222	*72*	0.208	*980*
4-5	0.183	*595*	0.256	*90*	0.281	*146*	0.378	*74*	0.221	*917*
6-7	0.166	*543*	0.231	*78*	0.312	*183*	0.405	*79*	0.221	*895*
8-10	0.127	*495*	0.298	*57*	0.276	*221*	0.413	*92*	0.207	*876*
11 and over	0.148	*236*	0.308	*26*	0.284	*169*	0.413	*63*	0.238	*500*
Overall average	0.170	*2506*	0.236	*365*	0.284	*865*	0.368	*380*	0.217	*4168*

TABLE 16

Accident involvement frequency by propensity to snore and by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven. *(Number of accidents in italics)*

Snores every night?	SLEEPY=1				SLEEPY=2					
	Private Car		Company Car		Private Car		Company Car		Total	
No	0.172	*2583*	0.246	*358*	0.287	*828*	0.348	*368*	0.216	*4204*
Yes	0.178	*174*	0.345	*29*	0.294	*85*	0.552	*29*	0.259	*321*

between those who snore every night and those who do not - i.e. the first three categories have been merged into one.

Clearly the numbers of accidents in which respondents who snore every night are involved is quite small, especially when disaggregated between the four sub-groups. However Table 16 suggests - as with the HGV drivers - that those who do snore every night have a higher accident liability than those that do not. Again, the statistical modelling to be reported in Section 7, will quantify this effect taking into account the interacting effects of the other variables.

6. FALLING ASLEEP AT THE WHEEL (CAR DRIVERS)

6.1 WHY DO DRIVERS FALL ASLEEP AT THE WHEEL?

As already indicated, respondents to the car driver survey were asked if there were any occasions in the previous twelve months on which they had felt close to falling asleep while driving (the factor SLEEPY); 29 per cent of the drivers reported that there were. An open-ended question asked what the circumstances had been, and the most common reasons are given in Table 17.

It is clear that the in the main, the reasons for feeling close to falling asleep at the wheel have to do either with general tiredness after long periods working or driving, or is related to having to drive during unsocial hours - although the survey did not collect any data which specifically related to the time of day respondents were driving. Illustrations given by drivers of occasions when they felt close to falling asleep at the wheel are given in Appendix D.

Drivers were also asked: "when making along journey, how many hours would you normally drive before taking a break?" Just under a third of drivers said that they would drive for 2 hours before taking a break, and about a third suggested 3 hours. However there was a significant minority (25 per cent) of drivers who would drive for 4 hours or more before taking a break.

6.2 THE PROBABILITY OF FALLING ASLEEP AT THE WHEEL

It seems likely that the probability of falling asleep at the wheel will depend on a number of factors including those relating to the individual characteristics of the driver and to the amount of driving undertaken. Appendix E describes a logistic regression model which quantifies the relationship between the probability of falling asleep at the wheel and

TABLE 17

Driving conditions suggested by car drivers as those which induce sleepiness while driving

Driving condition	Percentage of drivers
Long working day/physical or mental exertion	21
Motorway driving for long distances	19
Late night/early morning	15
Driving for long hours	9
Heater on/too warm	9
After working night shift	6
Lack of sleep	6
Other (including driving in the dark, poor visibility, glare of sun, boring journey)	15

those factors collected in the present survey which proved to be significant predictors. The continuous variables in the order they entered the model (i.e. in order of their explanatory power in predicting the probability of falling asleep at the wheel) are Epworth score, age, annual mileage, the proportion of time sent driving on motorways and roads in built up areas, and how long the driver is prepared to drive before taking a break. Also significant predictors of probability of falling asleep at the wheel are occupational group and whether the driver was driving a company car or not.

The best fit logistic regression model was as follows:

$$z = -1.668 + 0.135\mathbf{ESS} - 0.023\mathbf{AGE} + 0.0000333\mathbf{MILES} + 0.010\mathbf{MWAY} - 0.006\mathbf{BUA} + 0.054\mathbf{BREAK} \quad (1)$$

where, **P** (the probability of falling asleep at the wheel) = $e^z/(1 + e^z)$

ESS is the Epworth daytime sleepiness score,

AGE is the drivers age in years

MILES is annual mileage,

MWAY is the percentage of time the drivers spend driving on motorways,

BUA is the percentage of time spent driving on roads in built up areas,

BREAK is the number of hours a driver is prepared to drive before taking a break.

For drivers of company cars, 0.326 should be added to z in the above equation; for members of occupational group A/B add 0.872, and for members of occupational group C1 add 0.661.

The sense of these explanatory variables are generally as expected. A higher Epworth score considerably increases the probability that a driver will feel close to falling asleep at the wheel. Age has a negative effect, and annual mileage the expected positive effect. Neither frequency of trip making nor propensity to snore proved to be predictive of falling asleep at the wheel. However, not unreasonably, the probability of falling asleep at the wheel does increase with the proportion of time spent driving on motorways and decrease with the proportion of time spent driving in built up areas. Drivers who are prepared to drive for long periods without taking a break are also more likely to fall asleep at the wheel - though this latter effect is at the margins of statistical significance. Quite apart from the effect of higher mileages and more motorway driving, drivers of company cars do seem to be more likely to fall asleep at the wheel than private car drivers - for reasons which as suggested in 5.2 above, may be related to the circumstances and unsocial times of day when business trips have to be made.

The effect of occupational group was found to be modelled acceptably using a three level grouping - senior managerial, administrative or professional respondents (A/B), junior managerial, administrative and professional respondents (C1) and the other groups combined (C2, D and O). Appendix E gives details of the model terms and the standard errors, and provides a table indicating the magnitude of the various terms in the model. The model provides an excellent fit to the data with little residual unexplained variation.

Figure 2 illustrates the dependency of the probability of falling asleep at the wheel on Epworth score for four groups of drivers who drive 11,380 miles a year, who spend 21 per cent of their time driving on motorways and 47 per cent of their time on roads in built up areas, and who are prepared to drive for 2.9 hours before taking a break (the average values for the data set as a whole). The lower solid line is the fortuitously coincident relationship for two groups of

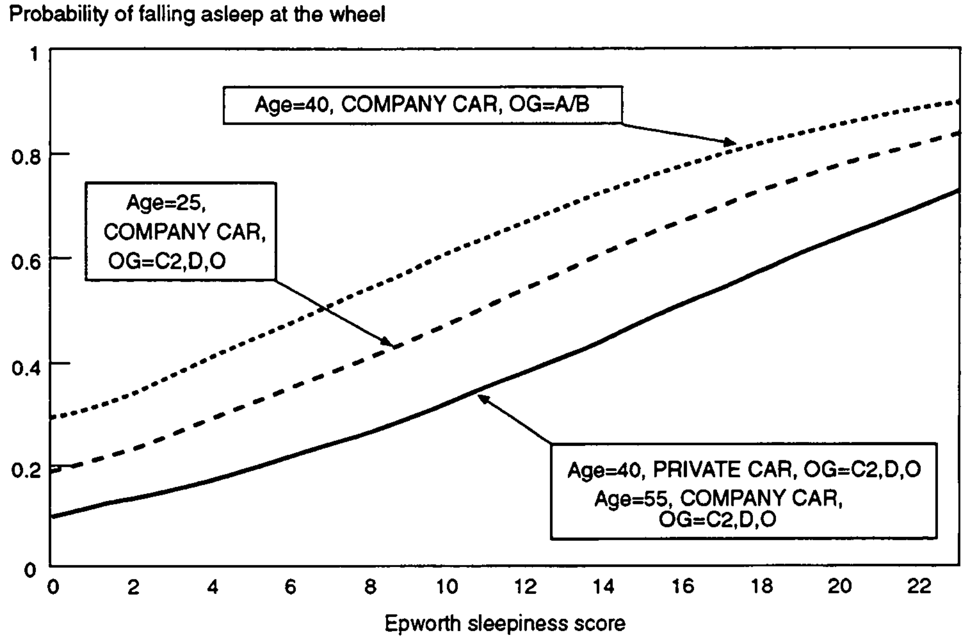

Fig. 2 The probability of falling asleep at the wheel as a function of Epworth score

drivers both belonging to occupational groups C2, D or O - 55 year old company car drivers and 40 year old private car drivers. The effect of age is illustrated by comparing the solid line for the 55 year old drivers with the central dotted line representing 25 year old drivers. The difference between the lower solid line and the upper broken line in Figure 2 illustrates for 40 year old drivers, the enhanced probability of falling asleep at the wheel for a company car driver in occupational group A/B compared with a private car driver in occupational group C2, D or E.

It can be seen from Figure 2 that over the range of the variables used in the modelling, the logistic model predicts that the probability of falling asleep at the wheel can vary from under 0.1 for mature, low exposure private car drivers, to over 0.9 for younger drivers driving high mileages in company cars.

6.3 MEASURES ADOPTED TO COUNTER SLEEPINESS

If a driver becomes aware of feeling sleepy, he may take measures to counter the effects. Respondents were asked to indicate from a list of 5 remedial measures (plus an 'other - please specify' category) the measures they found helpful in counteracting feelings of sleepiness; about 89 per cent of drivers responded to this question. Table 18 shows the responses in order of popularity, expressed as percentages of drivers responding to the question; since more than one response could be offered, the percentages add up to more than 100 per cent.

The 'other' category included suggestions ranging from the prosaic to the bizarre. The most popular among this cat-

TABLE 18

Measures found helpful by drivers in countering the effects of sleepiness whilst driving

Remedial Measures	Percentage of those responding to the question
Opening the window for fresh air	68 per cent
Stopping and taking a walk	57 per cent
Listening to the radio	30 per cent
Talking to a passenger	25 per cent
Drinking coffee	14 per cent
Other	15 per cent

egory were singing, eating, smoking, taking caffeine tablets, stopping and sleeping, washing one's face, letting someone else drive, and putting the seat upright (and less comfortable). Clearly it is a popular conception that fresh air, taking a break and listening to the radio are effective in countering the consequences of sleepiness. Experimental work currently in progress at Loughborough University should provide some indications of the extent to which these remedies are really effective.

7. ACCIDENT MODELLING

7.1 INTRODUCTION

The tabulations included in sections 4 and 5 above have shown that the accident involvement of drivers is related to age (in combination with driving experience), Epworth daytime sleepiness score and the frequency of snoring. In the case of car drivers, annual mileage was also an important factor, and for HGV drivers there was some indication that the physical characteristics potentially indicative of night-time sleep problems (obesity, collar size and nasality of speech) as assessed by the interviewers could also be related to accidents.

In order to explore the relationship between accidents and these variables it is necessary to use a multiple regression method based on the Generalised Linear Modelling (McCullagh and Nelder, 1985, Aitkin et al, 1992). The GLM technique as applied to driver accidents is described fully in Maycock and Lockwood, 1991; the principles are summarised in Appendix F.

7.2 THE FORM OF THE MODELS

The form of the relationships fitted to the HGV and car driver data respectively, are shown as equations (2) and (3) below:

$$A_3(\mathbf{HGV}) = K\exp[B_1/\mathbf{AGE} + B_2(\mathrm{SNORE,COLLAR})\mathbf{ESS}] \quad (2)$$

$$A_3(\mathbf{CAR}) = k\,(\mathbf{MILES} + 12{*}\mathbf{FREQ})^{\alpha}\exp[b_1/\mathbf{AGE} + b_2(\mathrm{SNORE,SLEEPY,CAR})\mathbf{ESS}] \quad (3)$$

where:

A_3 is the accident liability - the expected number of accident involvements a driver has experienced in the 3-year recall period based on reported accidents only - i.e. no correction has been made for accidents which have been forgotten.

AGE is the drivers age in years at the mid-point of the accident period. The reciprocal form of this term provides a more rapid fall of accident liability with increasing age than the simple exponential, and conforms to the optimum functional form found in other studies of accident liability (see for example, Maycock, et al 1991 and Forsyth, et al, 1995).

MILES and **FREQ** in equation (3), reflect the effect of driving 'exposure' on car driver accidents. MILES is the driver's estimated annual mileage, and FREQ is the frequency of driving expressed as the number of days per year a driver drives. Thus for example, for a driver who drives everyday, FREQ would be 365; for a driver who only drives once a fortnight, FREQ would be 26. The constant 12 in this expression has been determined interactively from the data, as that value which minimises the deviance of the model (see Appendix F).

ESS is the score on the Epworth Sleepiness Scale,

K,k are constants, and α, B_1, b_1, and B_2, b_2 are coefficients to be determined by the analysis; the terms in brackets associated with B_2 and b_2 implies that this coefficient is dependent on other factors as explained below.

It is of practical importance to note that in the case of both the HGV drivers and the car drivers, Epworth sleepiness score was a very much more significant predictor of accidents when included in combination with other categorical terms than when included as an overall predictive variable in its own right. This means that the effect of the daytime sleepiness is different for different groups of drivers; some drivers' accident liabilities are sensitive to daytime sleepiness whilst other drivers' are not.

In the case of the HGV drivers, the variables available for defining sub-groups in the population were those potentially indicative of night-time sleep problems namely, propensity to snore and the physical characteristics - collar size, obesity and nasality of speech - observed by the interviewers. Table 6 and Table 16 shows that in accident terms the only distinction worth making is between those drivers that do not snore every night and those that do. SNORE is the frequency of snoring coded as a 2-level factor which distinguishes these two groups both for HGV and car drivers. Table 7 showed that for HGV drivers any of the three physical factors (collar size, obesity and nasality of speech) seemed to be effective in distinguishing a higher accident group from a lower accident group. In a multivariate sense, these three factors are strongly inter-related, so that only one is useful as a predictive variable. Collar size proved to be the most effective of the three. COLLAR as used in the modelling, is a two-level category variable which distinguishes those HGV drivers judged by the interviewers not to have a large collar size from those that did.

In the case of car drivers, the 2-level SNORE factor also proved to be a useful means of splitting the population in to two groups with different responses to the daytime sleepiness variable. There was also a significant interaction between the effect of the Epworth scale and the 2-level category SLEEPY which distinguishes those drivers who had not felt close to falling asleep on some occasion during the last 12 months from those who had and between Epworth score and the factor CAR which distinguished drivers who mostly use a private car from drivers who mostly use a company car. The magnitude of these interactions will be illustrated in the sections which follow.

For car drivers an alternative model formulation based on the probability of falling asleep at the wheel was possible. The form of this alternative model is as follows:

$$A_3(CAR) = k\,(MILES + 12*FREQ)^{\alpha} \exp[b_1/AGE + b_2SNORE + b_3P] \qquad (4)$$

where the majority of terms are as before, but the coefficient b_2 is now dependent only on the 2-level factor SNORE, and the terms involving interactions between SLEEPY, CAR and the Epworth score (ESS) have been replaced by the term P, the probability of falling asleep at the wheel defined by equation (1).

7.3 MODEL RESULTS

7.3.1 HGV drivers

The 'best fit' model for HGV driver accidents based on the responses of the 941 drivers (and 241 accidents) for which data for all explanatory variables was available, is presented in Table 19. The Table shows the coefficients corresponding to equation 2 together with their standard errors. Their interpretation along with a brief discussion of the alternative variables and functional forms explored during the modelling will be presented below.

The 'multipliers' shown in Table 19 give an indication of the sensitivity of the accident frequency to changes in the explanatory variables. The model given by equation 2 is basically multiplicative. Because of this, the effects of the explanatory variables are most easily represented as factors which multiply a base accident frequency - represented in the last row of the Table 19 by the accident frequency of a driver of average age who does not have a large collar size (COLLAR=1) who does not snore very night (SNORE=1), and who does not suffer from daytime sleepiness (ESS=0). The multiplying factors in last two columns of Table 19 are then the values by which this base accident frequency has to multiplied when the explanatory variables take on values at the practical extremes of their ranges. Since the lowest Epworth score (ESS) is zero, the multiplying factor corresponding to this for all groups of drivers identified by the category variables SNORE and COLLAR is 1 (e^0). The multiplying factor corresponding to the highest value of the Epworth score has been calculated at ESS = 12 - approximately the 95th percentile point of the distribution. Where the coefficient of the term involving ESS is not statistically significant, the final column of the Table contains 'NS' signifying that the highest value multiplying factor cannot be regarded as being significantly different from 1.

The significance of the multiplying factors can be illustrated as follows. A 19 year old driver (the lowest end of the age range), with ESS=0, would have an accident liability 5.3 times the reference driver - i.e. an accident frequency of 0.164 x 5.3 = 0.87 accidents in a 3-year period. Alternatively, a driver of average age, who snores every night (SNORE=2) and who was judged by the interviewers to have a large collar size (COLLAR=2) would have an accident liability which ranged from the base value (0.164 accidents in 3 years) for an Epworth score of zero to a value of 2.7 times this (0.443 accidents in 3 years) at an Epworth score of 12.

The explanatory variables considered for inclusion in the accident model for HGV drivers are discussed in the following paragraphs.

(i) Exposure variables. Both annual mileage and the proportion of miles driven on motorways were tried as explanatory variables. As expected from the accident tabulations, neither proved to be statistically significant. For the record, annual mileage as the only term other than age included in the model fitted in the functional form (Accidents M^{α}) gave a value of α of 0.06 ± 0.1.

(ii) Age or driving experience. The accident tabulations showed that either age or driving experience are important predictors of accident liability. Age can be fitted in a number of functional forms. The reciprocal age term shown in Equation (2) proved to be effective for both HGV and car drivers. Because of the high correlation between age and driving experience, once the age term was fitted, a term reflecting the number of years a driver had been driving an HGV provided no improvement in fit. The age term must therefore be seen as the combined effect of age and driving experience.

Table 19 illustrates the size of the age/experience effect. A driver aged 19 (the highest value of the multiplier) will have an accident frequency which is over 5 times that of a driver of average age - all other things being equal. The 65 year old driver on the other hand (the lowest value of the multiplier) will have an accident frequency which is 40 per cent less than that of the driver of average age. This is a very large effect and in view of the relatively small numbers of drivers in the extremes of the age distribution, should be treated with some caution.

(iii) Daytime sleepiness in relation to collar size and snoring. The total Epworth score used as a single variable was just significant (5 per cent level) as a predictor of accidents once age had been included in the model. However, there were significant differences in drivers' sensitivity to the Epworth score within sup-groups of the driver population defined by the variables COLLAR and SNORE, variables which could possibly be related to impaired night-time sleep. As a result, Epworth score was much more effective if incorporated into the model as interacting with these category variables.

Table 19 shows that for the group defined by SNORE=1, COLLAR=1 - i.e. drivers who do not snore every night and do not have a large collar size (63 per cent of the drivers) - the coefficient of Epworth score is small and not significantly different from zero. That is to say, the accident liabilities of this group of drivers are not affected by daytime sleepiness as measured by the Epworth score. All the other groups are affected. The largest effect is for drivers who both snore every night and have large collar sizes (6 per cent of the drivers). For these drivers, those scoring 12 on the Epworth scale have 2.7 times the accident liability of those who score zero. In fact, the coefficients of ESS for drivers who either snore every night or have a large collar size or both, are statistically indistinguishable, and the model could be simplified by combining these groups.

7.3.2 Car drivers

7.3.2.1 The model using category variables (Equation 3)

The best fit model for car drivers which is based on the responses of 3904 drivers who between them had 847 accidents, is presented in Table 20. The Table shows the coefficients corresponding to equation (3) together with their standard errors. The interpretation of the coefficients given in the Table, are presented below.

As in the case of the HGV driver model, the 'multipliers' shown in the final 2 columns of Table 20 give an indication of the sensitivity of the accident liability to changes in the explanatory variables, and the principles of interpretation set out in connection with the HGV model applies equally to Table 20. In this case the base accident frequency is that of a car driver aged 48, who drives just over 300 times a year and in doing so covers 11,380 miles; if this baseline driver has not felt close to falling asleep at the wheel in the last 12 months (SLEEPY=1), drives a private car (CAR=1), does not snore every night (SNORE=1) and is not affected by daytime sleepiness (ESS=0), then he will have an accident liability of 0.166 accidents in 3 years - a figure virtually identical to that of the baseline HGV driver.

The explanatory variables included in the accident model for car drivers are discussed in the following paragraphs.

(i) **Exposure variables.** Annual mileage is a very strong predictor of accidents, though as other studies have found accident frequencies are not proportional to mileage. The incorporation of the frequency of driving (FREQ) term in equation (3) significantly improves the fit of the model. A similar result was obtained in the analysis of novice driver accidents (Forsyth et al, 1995).

The proportion of miles driven on motorways, built up and non-built up roads and the proportion of time the driver estimated he spent driving in the dark, were tried as explanatory variables in the model. Unfortunately, none of these variables significantly improved the model fit. As other studies have shown, these variables do not have large effects in predictive models of this kind.

TABLE 19

Model coefficients for the relationship between HGV accidents, age of driver and 'sleepiness' variables.

Variable	N		Coefficient and Standard Error	Accident multipliers Lowest value	 Highest value
Constant		k	0.0412	-	-
Age (AGE)		b_1	58 ± 8	5.3	0.6
Epworth Sleepiness Score (ESS):		b_2			
COLLAR=1, SNORE=1	596		0.006 ± 0.022	1	NS
COLLAR=2, SNORE=1	112		0.065 ± 0.025	1	2.18
COLLAR=1, SNORE=2	175		0.054 ± 0.025	1	1.91
COLLAR=2, SNORE=2	58		0.083± 0.034	1	2.70

Accident frequency for driver of average age (42) for whom COLLAR=1, SNORE=1, and ESS=0 is 0.164 per 3 years

TABLE 20

Model coefficients for the relationship between accident involvements, exposure, age of driver and 'sleepiness' variables for car drivers.

Variable	N		Coefficient and Standard Error	Accident multipliers Lowest value	Highest value
Constant		k	0.0015	-	-
Exposure (MILES+12*FREQ)		α	0.43 ± 0.06		
Age (AGE)		b_1	28 ± 3	2.4	0.9
Epworth Sleepiness Score (ESS):		b_2			
SLEEPY=1, CAR=1, SNORE=1	2200		-0.017 ± 0.013	1	NS
SLEEPY=1, CAR=1, SNORE=2	152		0.020 ± 0.024	1	NS
SLEEPY=1, CAR=2, SNORE=1	322		0.013 ± 0.020	1	NS
SLEEPY=1, CAR=2, SNORE=2	26		0.039 ± 0.047	1	NS
SLEEPY=2, CAR=1, SNORE=1	761		0.027 ± 0.012	1	1.38
SLEEPY=2, CAR=1, SNORE=2	77		0.037 ± 0.022	1	NS
SLEEPY=2, CAR=2, SNORE=1	340		0.044 ± 0.014	1	1.70
SLEEPY=2, CAR=2, SNORE=2	26		0.093 ± 0.024	1	3.05

Accident frequency for driver of average age (48) and average annual mileage (11,380) and average frequency of driving (302 times per year) for whom SLEEPY=1, CAR=1, SNORE=1, and ESS=0 is 0.166 per 3 years

(ii) Age or driving experience.

The accident tabulations showed that age was an important predictor of accident liability, and the reciprocal age term shown in equation (3) proved to be the most effective functional form for this term. Because of the high correlation between age and driving experience (the number of years since passing the L-test) in random samples of drivers, respondents were not asked for their driving experience in this survey. The age term in equation (3) - as in the case of the HGV driver model - must be seen therefore as the combined effect of age and experience.

The age effect for car drivers, is illustrated by the multiplying factors given in Table 20. If all variables other than age are held constant, a 19 year old driver will have an accident liability which is 2.4 times the base value (the figure shown in Table 20 under the column headed 'lowest value') - i.e. just under 0.4 accident involvements in 3 years, whilst a 65 year old driver will have an accident liability which is 0.9 times the base value (the figure shown in Table 20 under the column headed 'highest value') - i.e. just under 0.15 accident involvements in 3 years. There is therefore a factor of 2.7 (2.4/0.9) between the accident liabilities of young and old car drivers in this sample.

(iii) Daytime sleepiness in relation to falling asleep at the wheel, car type and snoring.

The Epworth scores of car drivers when included in the statistical model as a single variable results in a positive association with accidents which is statistically significant at the 5 per cent level. However, as in the analysis of the HGV driver accidents, the effectiveness of the Epworth score as a predictive variable in the model is considerably enhanced if it is used in the interactive form shown in Table 20. The driver data has been grouped into 8 sub-groups using the three 2-level factors SLEEPY, CAR and SNORE previously defined.

The magnitude of these sleepiness effects is indicated by the coefficients b_2 and the corresponding accident multipliers in Table 20. It will be immediately seen that due to the small sample sizes in some of the sub-groups, only 3 out of the 8 coefficients are statistically significant at the 5 per cent level. However, all three terms (SLEEPY, CAR and SNORE) provide highly significant improvements to the model when entered interactively with ESS as single terms, and there is a consistent pattern in the coefficient values shown in Table 20. If SLEEPY=1, CAR=1, SNORE=1 is taken as the reference value for which the coefficient of ESS is -0.017, then membership of any one of the second level groups increases the slope by about 0.03; membership of any two of the second level groups increases the coefficient by about 0.06, and for the sub-group SLEEPY=2, CAR=2, SNORE=2 the coefficient is increased by 0.11. That is to say, the sensitivity of accidents to changes in Epworth score is greater for the 32 per cent of drivers who have either felt close to falling asleep at the wheel in the last 12 months, or who drive an company car or who snore every night; it is greater still for the 11 per cent who fall into two out of the three categories, and greatest of all for the 1 per cent of company car drivers who both snore every night and have felt close to falling asleep at the wheel in the past 12 months.

The magnitude of these effects is illustrated by the multiplying factors given in Table 20. Since the lowest value of ESS will be zero for all drivers, the corresponding 'lowest value' of the exponential multipliers will as before be 1 (e^0). Those private car drivers (CAR=1) who have felt close to falling asleep whilst driving (SLEEPY=2) but who do not snore every night (SNORE=1) have an accident liability at the upper end of the Epworth scale (a value of 12 has been used here as for the HGV drivers) which is a factor of 1.38 (38 per cent) higher those scoring zero on the Epworth scale. Company car drivers who have felt close to falling asleep at the wheel but who do not snore every night, have an accident liability at ESS=12 which is 1.7 times a driver who scores zero on the Epworth scale (70 per cent higher), and the multiplying factor rises to 3 for those company car drivers who snore and who have felt close to falling asleep at the wheel. Thus for this admittedly small group of car drivers, daytime sleepiness over the range 0-12 as measured by the Epworth scale, has as large an effect on accident liability as an increase in age and driving experience from 19 to 65. It is noteworthy that the magnitude of this effect in car drivers is very similar to that in HGV drivers.

(iv) Obesity and collar size

In the HGV driver study, the characteristics of 'obesity' and having a 'noticeably large collar size' as judged by the interviewers, were significantly related to the accident liability of the HGV drivers. In the car driver survey, drivers were asked to record their height, weight and collar size. Obesity was calculated from height and weight according to the Body Mass Index (BMI) given in Black's Medical Dictionary:

$$\text{Obesity (BMI)} = \text{Weight (in Kilograms)/Height}^2 \text{ (in Metres)}$$

In the analysis of car driver accidents, neither obesity or collar size were significant predictors of accidents. It is virtually impossible to compare the obesity and collar size distributions of the car drivers in the present study with those of the HGV drivers in the earlier study, since the HGV study used subjective category assessments made by interviewers. It may possibly be the case therefore, that the car driver sample doesn't contain enough obese/large collar size drivers for any accident association to show through in the analysis. It is equally possible that the interviewers in making their assessments are drawing on characteristics of the HGV driver population which is not directly related to the numerical measures of obesity or collar size as obtained in the questionnaire survey. There is no obvious way of clarifying this issue.

7.3.2.2 The model using probability of falling asleep (Equation 4)

The alternative car driver accident model based on P - the probability of falling asleep at the wheel (equation (1)), is shown in Table 21.

The exposure and age effects are virtually unchanged from the model of equation (3). The factor SNORE distinguishing those who did not snore every night from those who did, and potentially indicative of a group of drivers with night-time sleep impairment problems, was not a useful predictor of the probability of falling asleep at the wheel (equation (1)). Nevertheless, it remains significant as a predictor of accidents in equation (4) as a simple 2-level factor. The coefficient b_2 associated with SNORE=2 now represents a simple accident multiplier indicating that car drivers who snore every night have an accident frequency which on average is 30 per cent higher than those who do not snore.

The probability of falling asleep at the wheel estimated by equation (1) is a significant predictor of accidents, such that drivers registering a probability of 0.95 on this scale have and accident liability which is 1.7 times those having a zero probability of falling asleep at the wheel.

7.4 ESTIMATES OF THE ACCIDENT EFFECTS OF SLEEPINESS

The accident modelling presented above provides an indirect way of estimating the overall effects of sleepiness on the number of accident involvements. Supposing the accident liabilities of all drivers were reduced to the liabilities of those who were not affected by daytime sleepiness (as measured by the Epworth scale), then the reduction in the expected accident involvements for the population as a whole, might be considered as representing the contribution of sleep-related involvements to the total. In reality, the links between daytime sleepiness as measured by the Epworth scale and sleepiness as a causal factor in individual accidents is not that direct. However, out of interest the calculation seems worth attempting.

In the case of HGV drivers, if all Epworth related effects were eliminated from the model based on equation (2) and Table 19, accident involvements would be reduced by 16 per cent (corresponding - see 3.1 to 16 per cent of accidents). The corresponding figure for car drivers based on equation (3) and Table 20 is 6.8 per cent of involvements

TABLE 21

Alternative model coefficients for the relationship between accidents, exposure, age of driver and the probability of falling asleep at the wheel for car drivers.

Variable		Coefficient and Standard Error	Accident multipliers Lowest value	Highest value
Constant	k	0.0015	-	-
Exposure (MILES+12*FREQ)	α	0.42 ± 0.07		
Age (AGE)	b_1	26 ± 3	2.4	0.9
Snore every night (SNORE=2)	b_2	0.28 ± 0.12	1	1.3
Probability of falling asleep at the wheel (P)	b_3	0.52 ± 0.21	1	1.7
Accident frequency for driver of average age (48) and average annual mileage (11,380) and average frequency of driving (302 times per year) for whom SNORE=1, and P=0 is 0.150 per 3 years				

(corresponding roughly to 9 per cent of accidents). Using equation (4), and setting the Epworth component of the probability of falling asleep at the wheel to zero, the estimate becomes 7.6 per cent of involvements (approximately 10 per cent of accidents). In the case of the car accidents these estimates are very close (probably fortuitously) to the proportion of accident involvements assessed as 'tiredness related' by the drivers themselves (see Table 10).

8. SUMMARY

8.1 INTRODUCTION

Although fatigue is a condition which is not particularly well defined and may involve a variety of physiological and psychological states, driver 'fatigue' is often cited as a cause of road accidents. Fatigue is likely to result in impaired performance, resulting in an increase in the risk of becoming involved in an accident. On any particular journey, a driver may suffer from fatigue or sleepiness for a variety of reasons - some associated with the task of driving, others to do with more general lifestyle or health factors.

Although the identification of sleep related accidents is problematic, the evidence from 'in-depth' studies, suggests that sleep may be a factor in between 10 and 25 per cent of accidents, the actual proportion depending on a range of factors including type of road, time of day and severity of accident. Studies that use 'officially reported' accident data - including data relating to injury accidents collected by a number of UK police forces - produce estimates of the involvement of fatigue in accidents ranging from 0.5 - 3.7 per cent.

In order to obtain information about fatigue or sleepiness as a factor in accidents from the drivers themselves, two surveys have been undertaken - one an interview survey of male Heavy Goods Vehicle (HGV) drivers and the other a postal questionnaire survey of male car drivers. The surveys were designed to obtain self-report data on sleep related accidents and to determine the relationship between sleepiness as measured by the Epworth daytime sleepiness scale and accident involvements.

8.2 HGV DRIVERS

In the survey of HGV drivers, just under 1000 HGV drivers were interviewed at motorway service areas. In the interview drivers were asked about their age, driving experience and annual mileage, and about the accidents they had experienced in the last three years. Each driver completed the Epworth Sleepiness Scale. Medical evidence suggests that there are certain physical factors which can in some individuals impair breathing during night-time sleep, resulting in excessive daytime sleepiness. These factors are obesity (particularly excess fat around the neck) and propensity to snore heavily during night-time sleep. Accordingly, drivers were asked about their propensity to snore at night, and the interviewers made subjective assessments about whether the drivers were obese and whether they had a large collar size.

The sample of drivers (996 in all) were evenly spread across the 20 - 60 age range; the average age was just over 41. The drivers covered an average of 69,700 miles per year, two thirds of which was on motorways. 205 of the drivers reported 252 accidents over a 3-year period of which 83.6 per cent did not involve injury. The data has been analysed to give tabulations of average accident frequencies (reported accident involvements per 3 year period) and by means of a multivariate statistical model.

The main findings of the analyses may be summarised as follows:

(i) ***Exposure Effects.*** There was no statistically significant relationship between accident involvement frequencies (per 3-year period) and annual mileage or percentage of driving time spent on motorways.

(ii) ***Age and driving experience.*** Accident frequencies are strongly dependent on the age of the driver: drivers in the 17-29 year old age group average 0.44 accidents in a 3-year period compared with 0.15 accidents per 3-years for drivers aged over 55. This reduction should be regarded as resulting from the combined effect of age and driving experience, the effects of which could not be separately identified in the analysis.

(iii) ***Daytime sleepiness.*** The 37 per cent of the driver population who either have a large collar size (as judged by the interviewers) or who snore every night - factors which are potentially indicative of night-time sleep problems - have accident liabilities which increase with daytime sleepiness as measured by the Epworth daytime sleepiness scale; drivers in these groups who score 12 on the Epworth scale (approximately the 95th percentile point of the distribution), have an accident liability which is twice that of drivers who do not suffer from excessive daytime sleepiness. There is no statistically significant relationship between accident involvements and Epworth score for the other 63 per cent of the HGV driver population.

The lack of a mileage effect at these high levels of annual mileage and the strong negative age effect are not unexpected. However, the relatively strong effect of daytime sleepiness for those individuals characterised as having a large collar size or who snore every night, is striking.

The observations of collar size, obesity and snoring were made because of a possible link between these characteristics and night-time sleep impairment including at the extreme, those suffering from sleep apnoea. However, since only about 0.3 per cent of HGV drivers had an Epworth score of more than 16 - a figure which according to Johns would indicate a potential apnoeic - the present findings cannot be interpreted as suggesting that sleep apnoea is a significant cause of accidents. It would appear nevertheless, that HGV drivers who tend to obesity, who do have large collar sizes and who snore every night, are over-represented in accidents, if they also suffer, for whatever reason, from excessive daytime sleepiness.

8.3 CAR DRIVERS

8.3.1 The survey

The postal questionnaire survey of male car drivers was based on just over 4600 responses from a structured sample of 9000 drivers. In addition to questions about age, exposure, occupational group, and propensity to snore drivers were asked about the accidents in which they had involved in the last three years of driving. In connection with the latter, drivers were asked whether 'tiredness' had contributed to any accident they might have had. Drivers completed the Epworth Sleepiness Scale, and indicated whether or not they had felt close to falling asleep at the wheel in the last 12 months. They were asked to report the methods they had found helpful in countering the effect of sleepiness whilst driving. Because company car drivers drive larger distances than private car drivers - a higher proportion of which is on motorways - it seemed possible that company car drivers would be particularly vulnerable to the effects of tiredness. Drivers were therefore asked whether they drove a privately owned car or a company owned car most often.

The average age of the sample was 48 with a fifth of the drivers in each of the three occupational groups A/B, C1 and C2. The average mileage for drivers in the sample was 11,380; not surprisingly, private car drivers drove rather fewer miles than the average, and company car drivers driving considerably more miles annually than the average. The 4621 drivers who responded to this survey reported 1003 accidents over a 3 year period, of which 12.5 per cent were injury accidents.

The data from this survey has been tabulated in the report in terms of 4 sub-groups defined by means of two 2-level factors - SLEEPY and CAR; SLEEPY is a factor which distinguishes drivers who had not felt close to falling asleep at the wheel in the past 12 months (SLEEPY=1) from those who had (SLEEPY=2); CAR distinguished those who mostly drove private cars (CAR=1) from drivers of company owned cars (CAR=2). In addition to the tabulations, the probability of being close to falling asleep at the wheel was related to other variables collected in the survey using a logistic regression. Accident liabilities (the expected number of accident involvements in the 3-year period) have been related to a range of variables using a multivariate statistical model.

8.3.2 Results: tiredness and accidents

(i) ***Falling asleep at the wheel.*** Drivers were asked about their experiences of falling asleep at the wheel and the countermeasures they believed to be beneficial in these circumstances. The responses may be summarised as follows:

- 29 per cent of drivers had felt close to falling asleep at the wheel in the past 12 months. The reasons given were generally related to tiredness after working or driving long periods, or involved driving during unsocial hours.

- A third of drivers said that they would normally take a 2 hour break when making a long journey and a further third suggested 3 hours. However, there was a significant minority of drivers (25 per cent) who would drive for 4 hours or more before taking a break.

- A logistic model showed that the following driver characteristics are influential in predicting the probability of feeling close to falling asleep at the wheel (sense of the effect in brackets): Epworth score (+ve), age (-ve), annual mileage (+ve), proportion of time spent on motorways (+ve) and built-up roads (-ve), how many hours a driver is prepared to drive before taking a break (+ve), whether driving a private or company car (company car drivers have higher probabilities than private car drivers) and occupational group (probabilities are highest for group A/B, followed by group C1 with C2, D and O having the lowest probabilities). Depending on these factors, the probability can range from below 0.1 to over 0.9.

- The principal methods suggested by drivers for countering the effects of sleepiness were: opening the window for fresh air (68 per cent), stopping and taking a walk (57 per cent), listening to the radio (30 per cent) and talking to a passenger (25 per cent). Drinking coffee came fifth, and was advocated by only 14 per cent of the drivers.

(ii) ***Tiredness as a factor in accidents*** Drivers were asked to identify factors which had influenced their role in the accident. The following summarises their responses:

- Tiredness was reported as being a factor in 7 per cent of the accident involvements in which the survey drivers had been involved. Making allowance for the fact that about one third of accidents involve two cars, the 7 per cent of tiredness related involvements probably means that tiredness is implicated in between 9 and 10 per cent of accidents. The other contributory factors cited (in order of popularity) were: inattention or distraction (24 per cent of accident involvements), misjudgment (15 per cent), visibility problems (11 per cent), driving too fast (8 per cent), driving too close to the vehicle in front (7 per cent), road surface fault (6 per cent), road layout fault (5 per cent) and lack of skill or inexperience (5 per cent).

- Tiredness as a contributory factor in accident involvements differed significantly on the three types of road: on motorways 15 per cent of involvements were tiredness related (20 per cent of accidents), on rural roads the proportion was 10 per cent (14 per cent of accidents), and on built-up roads, 5 per cent (7 per cent of accidents).

- Tiredness as a factor in accidents also differed significantly between the age groups with the older drivers being less likely to be involved in these accidents. This is probably due to the fact that older drivers drive fewer miles and are less likely to be driving when tired or at inappropriate times of day.

- Not surprisingly, tiredness-related accident involvements as a proportion of all involvements, are greatest in the early hours of the morning (27 per cent between midnight and 04.00 - corresponding to 36 per cent of accidents), falling to a minimum of 3 per cent (4 per cent of accidents) in the morning hours (08.00 to midday) and rising thereafter through the afternoon and evening periods.

8.3.3 Accidents and accident liability

Of the 4621 drivers who responded to this survey, 17.9 per cent had been involved in an accident in the last three years. The overall accident frequency (accidents in the last 3 years uncorrected for any accidents which may have been forgotten) was 0.217. However there were large variations in accident frequency depending on exposure (annual mileage and frequency of trip making), age, and Epworth score. These variations may be summarised as follows:

- As in the case of the HGV drivers, accident frequencies fell with increasing age. The multivariate model suggested that a drivers accident liability fell from just under 0.4 accident involvements in 3 years for a 19 year old driver to just under 0.15 involvements per 3 years for a 65 year old driver. This 'age' effect is to be regarded as reflecting the reduction in accidents resulting from the combined effects of increasing age and driving experience.

- Accident frequencies increase with both annual mileage and frequency of trip making, though the number of accidents is not proportional to these variables. Overall, drivers driving less than 5,000 miles annually, had an accident frequency of 0.120 accidents per 3 years, whilst those driving over 30,000 miles annually had an accident frequency of 0.435 (see Table 14).

- As in the case of the HGV drivers the effect of daytime sleepiness as measured by the Epworth scale was most marked for specific sub-groups of the driver population. In the case of car drivers the factors SLEEPY, CAR and SNORE provided significant sub-groupings in this respect. Those private car drivers (CAR=1) who have felt close to falling asleep whilst driving (SLEEPY=2) but who do not snore every night (SNORE=1) have an accident liability at the upper end of the Epworth scale (ESS=12) which is a factor of 1.38 (38 per cent) higher those scoring zero on the Epworth scale. Company car drivers who have felt close to falling asleep at the wheel but who do not snore every night, have an accident liability at ESS=12 which is 1.7 times a driver who scores zero on the Epworth scale (70 per cent higher), and those company car drivers who snore and who have felt close to falling asleep at the wheel, have at ESS=12, three times the accident liability of those who do not suffer from excessive daytime sleepiness (ESS=0).

In the survey of HGV drivers, obesity, and collar size in addition to the drivers propensity to snore were found to be useful identifiers of groups of drivers who are sensitive to daytime sleepiness. The same characteristics were collected in the survey of car drivers. However, neither obesity or collar size proved to be useful as predictors of accident involvement frequency. The distribution of Epworth scores for car drivers was very similar to that for HGV drivers. In the case of car drivers, only 0.8 per cent scored more than 16 on the Epworth scale, thus qualifying in Johns' terms as potential sleep apnoeics. Sleep apnoea seems unlikely therefore to contribute greatly to the problem of sleepiness and accidents for either HGV or car drivers.

It is clear however, that for some car drivers there is a significant problem of sleepiness and driving - a problem which brings with it a real increase in the risk of accident involvement. Those most at risk are drivers who are susceptible to daytime sleepiness as measured by the Epworth scale, and who drive high mileages in company cars,. For these drivers, the probability of being close to falling asleep at the wheel is alarmingly high; their accident liability may be between 2 and 3 times that of the driver who is not affected by daytime sleepiness.

9. CONCLUSIONS

It has always proved difficult from more traditional sources of accident data to identify the extent of the influence of fatigue in accidents. This study has focused on the relationship between sleepiness and accidents in the case of both HGV and car drivers, and has shown using self reported data, that 'tiredness' or 'sleepiness' as measured by the Epworth daytime sleepiness scale is indeed correlated with accident involvement.

The car drivers themselves are suggesting that overall, tiredness is a contributory factor in 7 per cent of accident involvements (estimated to be between 9 and 10 per cent of the accidents). On motorways, this proportion rises to 15 per cent (20 per cent of the accidents) and in the early hours of the morning the proportion is even higher.

Even if the 'direct' but subjective evidence of the car drivers themselves were not available - or not regarded as reliable - the significant relationship between the probability of being close to falling asleep at the wheel and variables such as Epworth score, age, annual mileage, proportion of time spent on motorways, and occupational group, provides strong indirect support for the involvement of sleepiness as a factor in driving safety.

HGV drivers were not asked about falling asleep at the wheel, nor were they asked to assess whether fatigue was a contributory factor in the accidents in which they were involved. However, for both HGV and car drivers, the evidence provided by the accident analysis for a positive relationship between accident frequency and Epworth score, provides a convincing indication that sleepiness is indeed a significant factor in accidents. It has been estimated from the statistical models that if the dependence between accidents and Epworth score were eliminated, HGV accident involvements would be reduced by 16 per cent and car drivers accident involvements by between 7 and 8 per cent (representing about 10 per cent of car accidents).

The role of the company car driver is also clear and dominant. Company car drivers, who are predominately younger drivers in occupational groups A, B and C1, who cover large annual mileages, a high proportion of which will be on motorways, and who probably travel long distances after a busy day at times when tiredness is likely to be a problem, have a particularly high probability of falling asleep at the wheel and a relatively high accident frequency. Although the constraints of work schedules will often require that business (need car) drivers travel long distances at inconvenient times, an awareness by the drivers themselves and possibly by their employers of the accident consequences of tiredness, could go some way towards minimising the road accident risks inherent in this part of the job.

It is important for drivers who find themselves in the position of having to drive whilst tired, to be able to identify effective countermeasures. Drivers when asked, suggested as countermeasures, opening a window, or taking a walk, or listening to the radio. In the view of many drivers, drinking coffee is relatively low down on the list of effective measures. It is clearly necessary to determine as objectively as possible, the relative effectiveness of alternative potential countermeasures.

This study has concentrated on male drivers. Women drivers are at present a smaller sector of the driving population and on average they cover considerably smaller annual mileages. However, the number of women drivers is increasing, and it may be that the number of women drivers who are driving company cars on business is increasing also. Whether women are more or less susceptible to tiredness and the consequent accident effects than their male counterparts is not known. It would in any case be reasonable to assume that any advice about fatigue and driving arising from the studies of male drivers reported here would also be appropriate for women drivers.

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APPENDIX A: THE EPWORTH DAYTIME SLEEPINESS SCALE

The form of the Epworth sleepiness scale as used when interviewing HGV drivers was as follows:

"How likely are you to doze off or fall asleep in the following situations, in contrast to feeling tired? Even if you have not done some of these things recently, try to work out how they would have affected you. Here is a card with a scale on it [show card to the driver]. Use the scale to choose the most appropriate number in each situation; as you can see, 0=never, 1 = slight chance of dozing, 2 = moderate chance of dozing, and 3 = high chance of dozing."

Item Number	Situation	Score
1	Sitting and reading	0 - 3
2	Watching TV	0 - 3
3	Sitting inactive in a public place	0 - 3
4	As a passenger in a car for an hour without a break	0 - 3
5	Lying down to rest in the afternoon when circumstances permit	0 - 3
6	Sitting and talking to someone	0 - 3
7	Sitting quietly after lunch without alcohol	0 - 3
8	In a car, while stopped for a few minutes in traffic.	0 - 3

APPENDIX B: THE HGV DRIVER SURVEY DATA

B.1 CHARACTERISTICS OF THE SAMPLE

Tables B1 and B2 shows the distribution of age and annual mileage of the drivers included in the sample of HGV drivers.

As can be seen from Table B1, drivers were fairly evenly spread over the 20 - 60 age range; the mean age was 41.4 years. A wide range of driving experience was also represented in the sample; the mean length of time drivers had been driving HGVs was 17.6 years. The correlation matrix shown below shows that age and driving experience were highly correlated (correlation coefficient 0.86) - a fact which means that either age or driving experience, but not both, can be used as an explanatory variable in the multivariate accident modelling.

Annual mileages reported by the HGV drivers ranged from 4000 to an improbable 275,000 with a mean of 69,700. Table B shows the distribution to be fairly uniform between 40,000 and 100,000 miles.

B.2 CORRELATIONS BETWEEN VARIABLES

Table B3 shows the Pearson bi-variate correlation coefficients between some of the key continuous variables.

The high correlation between age and experience is expected, as is the significant negative correlation between accidents and both age and experience. The negative correlation between mileage and age, indicates that older drivers tend to drive fewer miles.

TABLE B1

Driver's age.

Age	Number of drivers
21 - 29 years	154
30 - 39 years	283
40 - 49 years	304
50 - 59 years	206
60 years and over	45
Total	992

TABLE B2

Annual Mileage

Annual Mileage	Number of subjects
Up to 39,999	137
40,000 - 59,999	264
60,000 - 79,999	269
80,000 - 99,999	127
100,000 and over	193
Total	990

TABLE B3

Pearson correlation coefficients.

	NACC	MILES	AGE	EXP	ESS
NACC	1.00	0.17	**-0.20**	**-0.17**	0.05
MILES	0.17	1.0	**-0.07**	-0.04	**-0.11**
AGE	**-0.20**	**-0.07**	1.0	**0.87**	0.04
EXP	**-0.17**	-0.04	**0.87**	1.0	0.01
ESS	0.05	**-0.11**	0.04	0.01	1.0

Coefficients in **bold type** are significant at the 5 per cent level or better

where:

NACC	- Reported number of accidents (3-years)
MILES	- Annual mileage (in 1000s)
AGE	- Age (years)
EXP	- Number of years driving an HGV
ESS	- Epworth Sleepiness Scale

APPENDIX C: THE CAR DRIVER SURVEY DATA

C.1 CHARACTERISTICS OF THE SAMPLE

Tables C1 to C3 show the distribution of drivers by age, occupational group, and mileage, disaggregated into the 4 groups defined by the two factors SLEEPY (whether a driver had or had not felt close to falling asleep at the wheel in the last 12 months) and CAR (whether a driver drove mainly a private or a company car).

Table C1 shows that although the sampling method was designed to ensure a fairly even spread of ages, the overall response rates (final column of the table) show quite large variations with age. The lower response rates for the younger drivers may be partly explained by the possibility that being more mobile, their addresses on the DVLA driver licence file are more likely to be out of date.

Not surprisingly, most of the over 65 year old drivers drive private cars. In view of the fact that as Table C5 below shows, the Epworth Daytime Sleepiness Score is positively correlated with age, it is surprising that the proportion of drivers who have been close to falling asleep at the wheel declines for the older age groups. The obvious explanation for this effect is that although older drivers are more likely to suffer from daytime sleepiness than younger drivers, they do not drive as far each year as do the younger drivers (see Table C3), and do not need to drive at times when they would be at risk of falling asleep at the wheel.

Drivers were asked to classify themselves into the 5 'Occupational Group' categories shown in TableC2 - categories which had proved in earlier studies to be relevant to accident liability.

Table C2 shows that the Occupational Groups to which the respondents in the 4 sub-sets of data defined by the variables SLEEPY and CAR belonged, differed considerably. Not surprisingly, a far higher proportion of company car drivers were in the senior managerial, administrative or professional group (A/B) than is the case for private car drivers. Rather more interesting is the fact that of those drivers who have felt close to falling asleep at the wheel (SLEEPY=2), a higher proportion are in the occupational Group (A/B) than is the case for those who had not felt close to falling asleep at the wheel (SLEEPY=1). This effect could possibly be explained by exposure effects - 'sleepy' drivers being those A/B drivers who cover the greatest annual mileage.

Table C3 shows the distribution of annual mileage among the drivers illustrating the marked difference between those driving private cars and those driving company cars.

Table C4 shows estimates of the proportion of time respondents in the six mileage bands spent driving on the three road categories - motorways, roads not in built-up areas and roads in built-up areas. As can be seen from the Table, the proportion of mileage driven on rural roads (roads not in built-up areas) is roughly constant irrespective of mileage. Respondents who drive high mileages spend relatively more of their driving time on motorways at the expense of driving on roads in built-up areas.

C.2 CORRELATIONS BETWEEN VARIABLES

Table C5 shows the Pearson bi-variate correlation coefficients between some of the key continuous variables.

The significant positive correlation between accidents (NACC) and both the exposure variables (MILES and

TABLE C1

Distribution of driver's age - by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.

Age band	SLEEPY=1		SLEEPY=2		Total
	Private Car	Company Car	Private Car	Company Car	
					(Percentage of drivers)
17-24 years	12	11	18	7	13
25-34 years	11	19	20	19	14
35-44 years	13	20	18	29	16
45-54 years	15	26	19	32	18
55-64 years	20	21	16	13	19
65 years and over	29	3	9	0	20
Average Age	51	43	42	42	48
Total Numbers	*2784*	*387*	*919*	*401*	*4561*

TABLE C2

Distribution of respondents by Occupational Group - by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.

Occupational Group	SLEEPY=1		SLEEPY=2		Total
	Private Car	Company Car	Private Car	Company Car	
					(Percentage of drivers)
A/B Senior managerial, administrative or professional	12	40	25	53	21
C1 Junior managerial, administrative or professional	16	16	28	24	20
C2 Semi-skilled manual	20	28	19	14	19
D Semi-skilled and unskilled manual work	11	11	9	7	10
O Student, housewife/husband, retired, unemployed	41	5	19	2	30
Total numbers	*2828*	*387*	*921*	*397*	*4553*

TABLE C3

Distribution of annual mileage by whether the driver has felt close to falling asleep in the last 12 months (SLEEPY=2) or not (SLEEPY=1) and by type of car driven.

Annual mileage band	SLEEPY=1		SLEEPY=2		Total
	Private Car	Company Car	Private Car	Company Car	
					(Percentage of drivers)
Less than 5,000	27	11	11	3	21
5,000 - 10,000	35	15	24	7	28
10,000 - 15,000	25	19	34	17	26
15,000 - 20,000	7	18	15	14	10
20,000 - 30,000	5	20	11	29	9
Over 30,000	1	17	5	30	6
Average mileage	8,380	17,790	12,490	24,160	11,380
Total numbers	*2793*	*385*	*922*	*398*	*4570*

TABLE C4

Average percentage of driving time spent by drivers on three types of road by annual mileage

Annual mileage band	Motorways	Roads not in built-up areas	Roads in built-up areas
			(Percentage of drivers)
Less than 5,000	15	30	55
5,000 - 10,000	17	32	51
10,000 - 15,000	20	33	47
15,000 - 20,000	26	34	40
20,000 - 30,000	31	32	37
Over 30,000	42	28	30
Overall averages	21	32	47

TABLE C5

Pearson correlation coefficients.

	NACC	MILES	FREQ	AGE	ESS
NACC	1	**0.17**	**0.10**	**-0.15**	0.02
MILES	**0.17**	1	**0.39**	**-0.22**	0
FREQ	**0.10**	**0.39**	1	**-0.17**	0.02
AGE	**-0.15**	**-0.22**	**-0.17**	1	**0.06**
ESS	0.02	0	0.02	**0.06**	1

Coefficients in **bold type** are significant at the 5 per cent level or better

where:

NACC	- Reported number of accidents (3-years)
MILES	- Annual mileage
AGE	- Age last birthday (years)
FREQ	- Frequency of driving (number of occasions per year)
ESS	- Epworth Sleepiness Scale

FREQ) is to be expected, as is the negative correlation between accidents (NACC) and age. It is not surprising that there is a small but significant positive correlation between age and Epworth sleepiness score (ESS).

APPENDIX D: DESCRIPTIONS OF FATIGUE-RELATED ACCIDENTS: CAR DRIVERS

D.1 INTRODUCTION

If a respondent replied positively to the question: During the last twelve months have you felt close to falling asleep at the wheel?, they were asked to describe the circumstances associated with this experience. Some drivers provided specific examples of accident or potential accident situations, others described in more general terms the circumstances in which they had felt close to falling asleep at the wheel. Both types of comment are included below (Sections D2 and D3); they are not in any particular order.

D.2 ACCIDENT OR POTENTIAL ACCIDENT ACCOUNTS

Individual driver's descriptions of their fatigue related accidents are helpful in giving a realistic view of how this type of accident can happen:

1. I, with two other drivers, was returning home from Scotland in one go in the early hours of the morning. I nearly hit the Crash Barrier, when I fell asleep at the wheel.

2. Returning home (27 miles) from London on Motorway after work then the Theatre, about 11.30/12 midnight - I dozed off and scraped along the central barrier.

3. Dark clear night, some moon, straight, familiar derestricted road, no traffic - 1am. After a 2hr motorway drive and a long day attending a funeral, I think the cats eyes mesmerised me and I started to wander across road; passenger nudged me and I corrected.

4. Driving back from a weekend between Dumfries and Cummock, I mounted the verge and woke up. I was listening to a taped book. The reader had a "smooth" voice and I think that it may have lulled my senses.

5. Up to July 28 1993, I travelled 55 miles to London every week day to my school teaching job. The car journey took approx 90 mins. On the homeward journey I frequently felt sleepy and on one or two occasions actually lost consciousness momentarily, fortunately without causing an accident.

6. Driving on the M20 my elderly father was falling asleep (1500hrs) and it seemed to effect me. I had had 1 pint only and I just dozed off. I was awakened by the rumble strip. They are excellent, but should be wider.

7. Motorway driving late pm. - having driven to an event 4 hours away. The fatigue occurred on the return journey. I was in the central lane and momentarily dozed. The car drifted from its main course and I was brought round by the sound of a car horn.

8. Driving on a dual carriageway at about 2pm on my own, I fell asleep at a speed of roughly 30 mph. The road had a right hand bend, which I failed to negotiate, and drove

straight on, mounting the pavement. This immediately woke me up but I was unable to stop the car and subsequently hit a lamppost.

9. After being up all night waiting to fly home from holiday we got into Manchester at 4.30am and still had to travel 150 miles home. About half way I actually fell asleep on the M6; I was woken by the car swerving. It must have only been a split second but we will never be as lucky again. We stopped at the next services for five minutes rest and woke up three hours later. When it actually happens to you, you realise its better being three hours late for work than not getting there at all. After being on a plane for maybe 6 hours you think you can get in a car and drive for another 6 - but you cannot!

10. Driving on the M1, I felt dozy and thought perhaps I could make it to the next two Service Stations. However, I was spotted by Police Car, who stopped me and informed me that I was swerving from Lane to Lane. They escorted me to next Service Station with caution, making sure that I had stopped to rest before proceeding on.

11. Coming back from Scotland and sitting in a Traffic queue for 3 or 4 miles in warm dry humidity, then moving fast again, my eyelids just kept dropping and my head nodded once or twice.

12. Travelling from Invergordon to Liverpool (a long journey) after working all day, I fell asleep several times for a couple of seconds.

13. About 10 miles after passing a service area on Motorway I found myself falling asleep (felt perfect when passing area) and had to force myself to stay awake and keep going, knowing it is an offence to stop on a Motorway. This is where the law is a ass; it would be better to pull over and stop, than risk killing oneself and possibly others.

14. Fell asleep at wheel, drive down and along a grass bank. Awoke and managed to get car back up onto the Motorway.

15. Driving along outside lane of motorway and fell asleep at wheel. Side of car scraped central barrier.

16. Fell asleep at the wheel while driving through town. Collided with railings.

17. I was in a massive Motorway jam and accidentally lifted my foot off the brake with the result that the car moved 3 yards and hit the car in front. I believe I nodded off.

18. Driving to catch Ferry - couldn't take usual break. Fell asleep and hit curb. No accident (luckily!)

19. I was driving along the M1 when I felt sleepy, the car went on to the hard shoulder, when I heard the noise of the line when I was passing it I awoke.

D.3 CIRCUMSTANCES RELATING TO FALLING ASLEEP AT THE WHEEL

Rather than descriptions of specific accidents or near-accidents, the following are simple statements of the circumstances in which a driver has felt close to falling asleep at the wheel:

1. Regularly feel very tired whilst driving on long journey. The only real remedy is to park up and sleep for about 20 minutes.

2. At night travelling along motorways - it is very hypnotic.

3. Arriving by plane at 6am then driving home from Manchester airport to Formby.

4. Driving home to Cortbridge from Aviemore after a day's snowboarding.

5. After working for eight hours and then having to drive home again for up to 4 hours if I am away from home.

6. Always during motorway driving after some hours driving, especially if I have not eaten during the day.

7. Coming home from holiday driving from Devon to Edinburgh in the early hours of the morning.

8. When driving long distances and within having completed a day's work and had to drive 100 plus miles home.

9. After leaving a meeting at 23.30hrs for a 2hr drive home. Half way home felt drowsy stopped on hard shoulder. Walked 200 metres up and back; set air conditioning as low as it would go and continued home.

10. After long drive home (in Hampshire) from Glasgow. Long delays on M6 near J10 (as usual). No service area between J10 and Oxford (via M54, M40). By the time I reached the A34 I was within 55 miles of home - didn't seem any point in stopping. Those 55 miles were very difficult due to tiredness.

APPENDIX E: A LOGISTIC REGRESSION MODEL FOR FALLING ASLEEP AT THE WHEEL

The tabulations of annual mileage by the factors CAR and SLEEPY in Appendix C make it clear that drivers who had felt close to falling asleep at the wheel in the past 12 months (SLEEPY=2) were more likely to be high mileage drivers driving company cars. This finding suggests that it might be illuminating to examine the link between the probability of being close to falling asleep at the wheel and the other variables obtained from respondents in this survey. Accordingly, the SLEEPY factor was converted to a variable indicating the probability of the driver belonging to one or other of the two SLEEPY categories; for those not having been close to falling asleep at the wheel (SLEEPY=1), the new 'observed' probability variable would be 0, and for those who have been close to falling asleep (SLEEPY=2) the 'observed' probability variable would be 1.

Using this new variable as the dependent variable, logistic regression has been used to estimate how the probability of falling asleep at the wheel in the last 12 months depends on the variables and factors obtained in the survey. Using SPSS, a forward stepwise selection procedure was used with the following variables as potential explanatory variables: age, Epworth Sleepiness Score (ESS), annual mileage (MILES), frequency of driving, proportion of time spent on the three types of road - motorways (MWAY), roads not in built up areas, and roads in built up areas (BUA), driving in the dark, occupational group as a 3-level factor (OG3 - distinguishing the A/B group, the C1 group and the remainder - see 5.3.2 in the main report for definitions), whether the drivers drove mostly a private or a company car (the 2-level factor CAR), whether the driver snored every night or not (the 2-level factor SNORE), obesity, collar size and how many hours a driver would normally drive when making a long journey without taking a break (BREAK).

Table E1 (equation (1) in the main report) shows the resulting regression model based on those variables which proved to be significant at the 5 per cent level or better. The Table (and equation (1)) gives the value of the 'log odds' (Z) from which the probability of falling asleep at the wheel (P) can be calculated from:

$$P = e^Z/(1 + e^Z)$$

The goodness of fit of the model shown in Table E1 may be judged from the fact that the initial deviance (3904 data points) was 4824, whilst the final deviance with 3895 degrees of freedom was 4079. The SPSS goodness of fit statistic (generalised Chi-square) for the final model is 3871, showing that there is very little unexplained systematic variation remaining after the explanatory variables had been included.

Table E2 shows the probabilities predicted from the above regression equation as each variable in turn varies from its 5 percentile to its 95 percentile value, all other variables being fixed at the mean for the whole data set; the values in the body of the Table apply to drivers of private cars, in occupational groups (OGs) C2, D and O. The mid-range probability of feeling close to falling asleep at the wheel for this group of drivers (estimated at the average values of the dependent variables appropriate to the whole data set) is 0.20 as shown at the bottom of the Table. Shown also at the bottom of the Table are the relative probabilities for company car drivers in the same occupational groups (0.26) and company car drivers in occupational group A/B (0.46)

The Epworth daytime sleepiness score is the single most sensitive variable, but the exposure variables are also very influential. Because the proportion of time spent driving on motorways and on roads in built-up areas are not independent, one range is shown for the two variables in combination. In fact of course, the time spent on the different types

TABLE E1

Regression model predicting the log odds of falling asleep at the wheel.

Variable	Coefficient (Z)	S.E.
Constant (Private car drivers, occupational groups C2, D and O)	-1.668	0.229
Epworth Sleepiness Score (ESS)	0.135	0.011
Occupational Group:		
Senior managerial (A/B)	0.871	0.097
Junior managerial (C1)	0.660	0.097
Age	-0.023	0.003
Annual mileage (MILES)	$3.33\ 10^{-5}$	$0.44\ 10^{-5}$
Proportion of time spent on motorways (MWAY)	0.010	0.002
Company car drivers (CAR=2))	0.330	0.103
Proportion of time spent on roads in Built-up areas (BUA)	-0.006	0.002
Number of hours driving before taking a break (BREAK)	0.054	0.029

TABLE E2

Sensitivity of the probability of feeling close to falling asleep at the wheel to the variables included in the regression.

Variable	Percentile range				Probability range
Epworth Score (ESS)	5 % ile:	0	95 % ile:	12	0.10-0.36
Age	5 % ile:	21	95 % ile:	73	0.30-0.12
Annual mileage (MILES)	5 % ile:	1,200	95 % ile:	30,000	0.15-0.32
Proportion of time spent on motorways (MWAYS)	5 % ile:	0 %	95 % ile:	70 %	0.15-0.32 (MWAYS and BUA combined)
Proportion of time spent on roads in built-up areas (BUA)	95 % ile:	60 %	5 % ile:	10 %	
Number of hours driving before taking a break (BREAK)	5 % ile:	2	95 % ile:	5	0.19-0.22
Mid-range probabilities:	Private car drivers, OGs C2, D and O:			0.20	
	Company car drivers, OGs C2, D and O:			0.26	
	Company car drivers, OG A/B:			0.46	

of road is not independent of the annual mileage either, so that for annual mileage combined with the variables specifying the proportion of time spend on motorways and built-up roads, the probability P ranges from 0.11 (with MILES and MWAYS at their 5 percentile values and BUA at its 95 percentile value) to 0.46 with these exposure variables at the opposite percentile limits. If to the exposure effects is added Epworth score, the probability range extends from 0.05 for a low mileage, low ESS driver to 0.65 for a high mileage, high ESS driver. If in addition, the driver is young, belongs to one of the other occupational groups, and drives a company car, the probability of feeling close to falling asleep at the wheel rises to over 0.9.

Generally, the model indicates that A/B drivers have the highest probability of falling asleep at the wheel even when the effect of the other variables (including exposure) have been allowed for; junior managers (C1) have a rather lower probability of falling asleep at the wheel, and the majority of drivers - i.e. those falling into the other occupational groups - have the lowest probability. Company car drivers are more likely to fall asleep at the wheel than drivers of private cars - even when the other factors included in the model have been allowed for.

APPENDIX F: STATISTICAL MODELS FOR ACCIDENTS

F.1 MODEL STRUCTURE

A statistical model has three components: (i) a systematic component - the relationship between the dependent variables (accident frequency) and the significant explanatory variables, (ii) the sampling error associated with the dependent variable, and (iii) the errors due to the lack of fit of the model. The lack of fit component may arise either because incorrect functional forms have been used for those variables included in the model, or because some key variables have not been included at all.

In the case of the logistic model (Appendix E) the assumed error distribution was binomial. In this Appendix the statistical models are fitted to reported accident frequencies, and since it is reasonable to treat accidents as though they were random events, the most appropriate error model is the Poisson distribution. This means that if the model fitted perfectly, the actual number of accidents a driver would experience in a year would be represented by a Poisson process whose mean value is given by the model prediction (the individual driver's accident liability). In fact, the accident models given in this report explain just over 50 per cent of the non-Poisson variability in the data. This means that the residuals are over-dispersed compared with a pure Poisson process. This over dispersion can be handled in a number of ways (see for example, Aitkin et al, 1992). Since in the present case, the over dispersion is not large as a proportion of the total residual variability, the 'quasi-likelihood' approach is used in which the errors calculated by the fitting process are increased by a factor $(X^2/\text{degrees of freedom})^{0.5}$, where X^2 is the generalised Pearson chi-squared statistic which for a Poisson variable is:

$$X^2 = (y - \mu)^2/\mu$$

y are the observed values and μ the fitted values.

F.2 FITTING THE MODELS

The models have been fitted using the Generalised Linear Modelling package GLIM4 (National Algorithms Group, Oxford).

To assess whether a new explanatory variable is worth including in the model, or whether a term is being included in the most appropriate functional form, goodness of fit is judged using a likelihood ratio statistic called 'scaled deviance'. Providing that the mean value of the dependent variable is greater than about 0.5 the scaled deviance with Poisson errors is asymptotically distributed as a chi-squared variable with n-p-1 degrees of freedom (where n is the number of data points and p the number of independent variables included in the model). When the average mean value of the dependent variable falls below 0.5 (as is the case with accident frequencies in the present study) the deviance of the final model cannot be used as an overall measure of goodness of fit since it ceases to be a chi-squared variable under these conditions. Instead the generalised Pearson chi-squared statistic X^2 (defined above) is appropriate. Fortunately, providing over-dispersion in the data has been allowed for, the deviance *differences* obtained when new terms are added to the model are still chi-squared variables so a comparison of deviance difference with the appropriate point of the chi-squared distribution can be used to assess the significance of adding terms or modifying functional forms of the terms already included. Thus, if only one additional explanatory variable is being added to a model, the change in deviance has to reach 3.84 (the $p = 0.05$ point of the chi(1)-square distribution) to be significant at the 95 per cent level.

Variables may be introduced into the models as continuous variables or as multi-level factors which are available in the form of categories within the data. In the case of factors, deviance difference is used to assess the usefulness of the factor as a whole - including all the levels; the significance of the individual levels have to be assessed using the standard errors computed by GLIM for the individual categories.

F3. SOME ASPECTS OF MODEL DEVELOPMENT

F3.1 INTRODUCTION

The coefficients and their standard errors of the base model are given in the main report. There are however a number of aspects of the modelling worthy of reporting here; they concern the Epworth Sleepiness Scale, road type effects and memory loss.

F3.2 THE EPWORTH SCALE

In order to explore the consistency of the individual items of the Epworth Scale for accident prediction, a base model was fitted to both the HGV and car driver data which included as appropriate, age and exposure effects. The individual elements of the Epworth scale were then fitted individually to this base model. The results are shown in Table F1.

It will be seen from Table F1 that with the exception of item 3 for HGV drivers, none of the individual coefficients are statistically significant. All but one are however positive - supporting Johns comment regarding the internal consistency of the scale (Johns, 1992). When combined, the individual Epworth responses provide a daytime sleepiness scale which results in a positive association with accidents which is just about statistically significant at the 5 per cent level when used as a predictor for all drivers in the sample, but which proves to be highly significant when applied to sub-sets of the drivers as discussed in the main report.

F3.3 THE EFFECTS OF ROAD TYPE FOR CAR DRIVER ACCIDENTS

Tables F2 gives some basic statistics relating to the proportion of time spent driving on the three road types (motorways, built up roads and non-built up roads) by the 4545 car drivers reporting this information.

Since the proportions of time spent on the three road types must add up to 100 per cent, when two of the road-type variables are included in the type of statistical model being used in this study to explore accident liability, the third variable is 'aliased'. A measure of the relative sensitivity of the effect of the three road types in predicting accidents can however be obtained by fitting all three variables to the *residuals* of the accident model; the coefficients (given in Table F2) then become the values of the coefficients c in the following equation:

$$A = A_{Predicted}(1 + c_m p_m + c_b p_b + c_n p_n)$$

where the p_m, p_b, and p_n are the percentage of time spent on motorways, built up roads and non-built up roads respectively. It will be seen that although the sign of the effects are as expected, none of the road-type variables significantly improve the predictive power of the model.

F3.4 MEMORY LOSS EFFECTS

Both the HGV drivers and the car drivers were asked to give the date of the accidents in which they had been involved.

In the case of the HGV drivers, 252 accidents were reported of which 221 were dated. If it is assumed that age and experience effects will only account for a small reduction

TABLE F1

Coefficients and standard errors for components of the Epworth Sleepiness Scale once Age and exposure effects have been allowed for.

Epworth component: How likely are you to doze in the following situations:	HGV drivers Coefficient	S.E.	Car drivers Coefficient	S.E.
1. Sitting and reading?	-0.02	0.07	0.05	0.04
2. Watching TV?	0.03	0.06	0.01	0.04
3. Sitting inactive in a public place?	0.32	0.09	0.09	0.06
4. As a passenger in a car for an hour without break?	0.06	0.06	0.05	0.04
5. Lying down to rest in the afternoon when circumstances permit?	0.07	0.06	0.06	0.03
6. Sitting and talking to someone?	0.01	0.23	0.17	0.10
7. Sitting quietly after lunch without alcohol?	0.10	0.07	0.02	0.04
8. In a car while stopped for a few minutes in traffic?	0.23	0.20	0.04	0.10

TABLE F2

Proportion of driving time by road type as predictors of accident liability

	Proportion of driving time				Model results	
	Mean	S.D.	Minimum	Maximum	Coefficient	S.E.
Motorways	21.0	19.8	0	100	-0.0001	0.001
Built up roads	47.2	23.8	0	100	0.001	0.001
Non built up roads	31.8	21.9	0	100	-0.001	0.001

in accidents over the period of three years, and that there have not been dramatic changes in driving patterns, it is to be expected that the number of accidents occurring in the three individual years of the survey would be much the same. In fact, the proportions of the 221 accidents ascribed to the three separate years of the recall period were respectively 62.4 per cent, 22.2 per cent and 15.4 per cent for the most recent year, the next most recent year and the year before that. These figures indicate that there is a large shortfall of reported accidents in the earlier years - presumably due to lapses of memory on the part of the drivers. In fact, as will be seen shortly, the memory loss effect for HGV drivers is considerably greater than was the case for car drivers.

The poor recall of HGV drivers' accidents suggests that there is little benefit for surveys of this kind in asking drivers in interview surveys to provide self-report data about accidents over a period of more than one year. It also means that the absolute accident rates reported in the following section - based on the 'nominal' three year total - are likely to be about half the true rates. Fortunately, an investigation of the interaction between memory loss and the other significant accident predictors shows that the results of the analyses reported in the main report have not been influenced by these forgotten accidents.

In the case of car drivers, of the 1003 accidents reported, 852 (85 per cent) were satisfactorily dated. In this case, the proportions of the dated accidents ascribed to the three separate years of the recall period were respectively 44.6 per cent, 33.5 per cent and 21.9 per cent for the most recent year, the next most recent year and the year before that. This implies that the memory loss effect for the car drivers averages about 29 per cent per year - a value not significantly different from that found in a study of car driver accidents (Maycock and Lockwood, 1991). The poor recall of car drivers' accidents means that the true accident rates are likely to be about 1.7 times those based on the number of accidents recalled by drivers in the three year period. Fortunately, as in the case of HGV drivers, memory loss effects have not influenced the relationship between accidents and the explanatory variables included in the accident models described in the main report.

F4 MODEL: GOODNESS OF FIT

Table F3 gives the value of generalised chi-square (see F1 above) for both the HGV and car driver accident models with only the overall mean fitted (the initial value), and for the final 'best fit' model. On average a Poisson data set will provide one unit of generalised chi-square for every degree of freedom. The difference between the initial value of chi-square and the number of degrees of freedom can therefore be regarded as the non-Poisson variation in the data to be explained by the model. The final value indicates the magnitude of the residual non-Poisson variation which remains after the model has been fitted. The percentage of non-Poisson variation explained is then calculated from these values.

TABLE F3

Initial and final values of generalised chi-square

	HGV model	Car driver model
Initial value	1153	4808
Degrees of freedom	940	3904
Final value	1035	4334
Degrees of freedom	935	3893
Percentage of non-Poisson variation explained	54 %	52 %

MORE INFORMATION FROM TRL

TRL has published the following other reports on this area of research:

TRL168	Falling asleep at the wheel. J A Horne and L A Reyner (Sleep Research Laboratory, Loughborough University). Price Code J.
RR315	The accident liability of car drivers. G Maycock, C R Lockwood and Julia Lester. Price Code C.
PR111	Cohort study of learner and novice drivers, Part 3: Accidents, offenses and driving experience in the first three years of driving. E Forsyth, G Maycock and B F Sexton. Price Code J.
PA3081/95	Behavioural Research in Road Safety V. Proceedings of a seminar at Nottingham University, September 1994. Ed G B Grayson. Price Code E

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