Loughborough University

Bus Driver Fatigue

Final Report

Transport Safety Research Group

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Glossary of abbreviations

Term	Acronym	Definition
Blood alcohol concentration	BAC	The percentage of alcohol in the blood stream.
Body Mass Index	BMI	The measurement based on height and weight to determine whether or not an individual is overweight
Electrocardiogram	ECG	A physiological measure used to examine heart rate
Electrooculography	EOG	A physiological measure used to examine blink duration
Epworth Sleepiness Scale	ESS	A subjective scale used to determine daytime sleepiness
Fatigue risk management system	FRMS	An evidence based, data-driven process which measures fatigue risks
Heart rate variability	HRV	The variation in the time between heart beats. A faster heartbeat would lead to a lower HRV
Health and Safety Executive Fatigue Risk Index	HSE FRI	A tool used to determine the risk arising from fatigue associated with a particular work schedule or shift
Karolinska Sleep Questionnaire	KSQ	A questionnaire used to measure subjective sleep and sleepiness
Karolinska Sleepiness Scale	KSS	A subjective rating scale of sleepiness ranging from 1 (highly alert) to 9 (having to fight to stay awake)
Obstructive sleep apnoea	OSA	A sleep disorder characterised by interrupted breathing during sleep
Randomised Control Trial	RCT	A method for evaluation an intervention in which people are randomly allocated to a group receiving an intervention, or a group not receiving an intervention
Root mean square of the successive differences	RMSSD	A statistical tool used to assess heart rate variability
Standard deviation	SD	A statistical measure of distribution of scores used to show the range of responses
Sleep efficiency	SE	Total sleep time, expressed as a % of time in bed
Sleep onset latency	SOL	The time between going to bed and falling asleep
Stockholm University Stress Scale	SUS	A subjective rating scale of stress ranging from 1 (highly relaxed) to 9 (very stressed, at the limit of what I can do)
Total sleep time	TST	The total amount of time spent asleep as shown by actigraph data

Executive summary

Bus drivers are exposed to a wide range of occupational factors that potentially increase their vulnerability to fatigue, including prolonged driving conditions, 24-hour operations, variable shift patterns, and urban traffic congestion. The nature of the job also limits the degree of control that drivers have over the timing of breaks, their sleeping patterns, diet and opportunity to exercise, which can further exacerbate the risk of fatigue-related problems. Despite these risk factors there has been a lack of research investigating fatigue in city bus drivers. Across six research tasks the current work demonstrates that fatigue is a problem for London bus drivers. The contributing factors to fatigue are wide and at times complex. There is a lack of current policy and regulation pertaining to fatigue leading to inconsistencies between operators. Across all operators, drivers report feeling unable to discuss fatigue with their employer and employers face difficulties in knowing how best to manage fatigue. A series of potential solutions are proposed across five key areas (education, working conditions, schedules, open culture and health).

Transport for London (TfL) requested independent research services regarding fatigue in London bus drivers. The research reported here was commissioned by TfL to understand the present situation with regard to fatigue and this report provides a roadmap to investigate solutions and to delve deeper into some of the observations made by the authors. This project sought to understand the extent and nature of fatigue, the contributing factors to fatigue, and what solutions could be implemented to address fatigue. The key components of this report are 1) a targeted literature review focusing on sleepiness and fatigue amongst bus drivers, and a broader review of fatigue prevention strategies, 2) a review of internal policy for managing fatigue, 3) focus groups with bus drivers, 4) interviews with managers, 5) a survey of bus drivers, 6) on-road observation study, and, 7) discussion of potential solutions.

Extent and nature of fatigue: Taking into account the findings from each task it can be concluded that fatigue is present. 21% of survey respondents indicated that they have to fight sleepiness at least 2-3 times a week, and 36% of respondents had a ‘close call’ due to fatigue in the past 12 months. Multiple examples of fatigue were discussed during each focus group, with managers also showing an awareness of fatigue during interviews. Despite the small sample it was observed first-hand in the on-road study with drivers obtaining an average of 4 hours and 50 minutes sleep before an early morning drive, with objective measures of sleepiness later being observed during data collection.

Key causes of fatigue: A wide range of factors contribute towards driver fatigue. Not every driver may experience every factor, and the impact of any particular factor varies for any specific driver at different times. Across each of the research tasks several key contributors to fatigue were apparent, these include: shift work and shift irregularity, sleep quality and quantity, overall health of drivers, a disciplinary culture, stress and mental overload whilst driving.

Potential solutions: Potential solutions are proposed across five areas. Several of the solutions and overall themes overlap or complement each other, supporting the notion of a holistic approach, encompassing or addressing aspects of each of the themes, to provide the most benefit in terms of reducing fatigue. It should be noted that none of the proposed solutions have been formally evaluated. Across each of the proposed solutions, there is a need for a shared responsibility. All parties (drivers, managers, operators at all levels, TfL, borough councils, unions, and the Department for Transport [DfT]) have a part to play in implementing any proposed solution. In order for any solution to be successful, parties must not give up too early. There is no quick fix for reducing fatigue and a long-term commitment is needed. With this, it is important to have a step-by-step approach in

which small changes are implemented to start with at a level which will be acceptable to all parties. After this acceptance a more sophisticated solution may be implemented over time. The proposed solutions are broadly split into five categories:

Education: Providing education to drivers on the importance of good quality sleep, sleep management, and the drivers responsibility to manage their sleep. Education should also extend beyond drivers to include managers, shift schedules, and operators as a whole.

Working conditions: Providing and ensuring regular evaluation of suitable facilities for drivers to eat and rest, as well as keeping buses well-maintained to reduce driver stress.

Schedules and rosters: Working to ensure that the design of schedules takes driver fatigue into consideration. This includes changes relating to protecting rest and break times, reducing variability in shift start times, increasing running times, using forward rotations, and avoiding spread-overs.

Open culture: Moving away from a discipline-based culture, to an open culture in which drivers feel comfortable talking about fatigue related issues. This includes improving the relationship between drivers, managers and controllers, increasing the ability to report near misses, and forming a fatigue working group which also includes drivers. A further aspect of an open culture would be an openness to new technology including aspects such as using biomathematical models for fatigue roster modelling.

Health (including sleep health): Creating interventions aimed at improving the overall health of drivers (and subsequently improve their sleep and wellbeing). This could include things such as reducing driver stress, providing health screenings, and providing suitable healthy food options for drivers.

It should be noted that these solutions were informed by the results obtained in the six tasks of this project. Although certain solutions may have been implemented across other occupational settings, the solutions discussed in this report have not yet been evaluated amongst bus drivers. The six tasks are summarised below:

Literature review: The first task was a targeted literature review which found only 26 scientific papers specifically investigating sleepiness and fatigue amongst bus drivers. In contrast, a search for truck driver fatigue using Scopus, returned 384 scientific papers. The small number of available papers demonstrated that this topic is under researched. This is likely due to the risk of fatigue/ sleepiness amongst bus drivers having been underestimated. Nevertheless, a review of previous driving research has shown that the risk of being involved in accident more than doubles when driving fatigued. Some key contributors to fatigue amongst bus drivers were identified in the literature review, these include: shift schedules, driving regulations, tight routes and time pressures, and working conditions. The literature also contained some suggestions for how to counteract sleep and prevent fatigue amongst bus drivers. These included: education, fatigue monitoring/ detection technology, improvements to bus conditions, and schedule changes. However, there is minimal research which has investigated the effectiveness of countermeasures amongst bus drivers.

Policy review: Task 2 was a review of the fatigue management policies from the 10 London bus operators. This review showed that at the time of review none of the 10 operators had a formal or specific fatigue policy, however most operators recognised that fatigue was an issue that needed to be addressed. Although all operators are following legislations relating to driving hours and rest periods, only two operators reported having additional parameters in place to ensure drivers do not become fatigued.

Driver focus groups: For task 3, focus groups were conducted with small groups of 6-8 drivers from each of the 10 operators. Across all of the sessions fatigue was seen to be a problem, with all drivers having experience, or knowing about such an experience in others, of feeling sleepy whilst driving the bus. However, fatigue is not discussed between drivers as a general rule. From these focus groups, several factors were identified as contributors to fatigue, these include: working overtime, staying up too late and therefore having insufficient sleep, spending time with family, other non-work commitments, shift schedules, and work pressure.

Manager interviews: Managers who would respond if a driver reports feeling tired, or if a driver has an incident appearing to be caused by fatigue/sleepiness were nominated by each of the ten London bus operating companies and interviewed. From the interviews it was clear that managers recognise that fatigue is a problem, for example, seeing it as a contributor to serious incidents. As a result, managers wanted to create a more open culture in which drivers feel comfortable talking about fatigue and sleepiness. However, whilst managers would encourage drivers to report fatigue, results from the driver focus groups showed that generally drivers did not feel comfortable reporting instances of fatigue for fear of being disciplined.

Driver survey: For task 5, an online survey was open to all London bus drivers (total = ~25,000), with 1,353 completing the survey. The survey questions specifically looked at drivers' work, sleep, health, and some general background information. The results of the survey showed that fatigue/ sleepiness is a problem for drivers, with 21% reporting that they have to fight sleepiness at least 2-3 times a week whilst driving the bus. A variety of factors in relation to sleep quality and quantity, work, and health emerged as contributors to fatigue amongst bus drivers.

On-road study: The final research task (task 6) was an on-road study focusing on a small group of drivers on a single route through London. This study was the first of its kind to conduct an on-road investigation on a live bus route. Buses and participating drivers were equipped with recording equipment to measure vehicle metrics (such as GPS) and physiological measures (blink duration and heart rate). Drivers took part in the study twice, once during an early morning drive and once during a daytime drive. Prior to these drives, drivers recorded their sleep in a diary and wore a motion watch to obtain objective sleep measures. Although there were no road crashes during the on-road study, the results showed that most drivers did not obtain sufficient sleep prior to early morning drives. It was hypothesised that sleepiness would be most present in the early morning drive, however sleepiness/ fatigue was observed in both drives. This is likely due to two different types of sleepiness/ fatigue being present. In the early morning drive sleepiness is likely a result of working during circadian lows and not obtaining enough sleep, whilst fatigue in the daytime drive is likely a result of completing a highly demanding task.

Future challenges: Although this report demonstrates that fatigue is a problem amongst London bus drivers, there are a few limitations. First, the samples used in each research task may not be fully representative of all London bus drivers. Although steps were taken to ensure that a wide variety of drivers were able to participate in the research, it is not possible to include the views and experiences of all London bus drivers in this project. Furthermore, there is a possibility that the drivers who opted to take part in this research are those who have experienced, or have a particular interest in, fatigue. There were also logistical difficulties inherent in planning and executing the on-road study, which led to cases of missing data. The on-road study was also limited in terms of time and mileage as the research was only conducted on one London bus route. As such, further research across more routes and different shifts would be useful. Another limitation is that the proposed solutions for reducing bus driver fatigue have not yet been subject to randomised control trials.

These limitations show that further research is needed. Further research may focus on expanding the data collected in the on-road investigation, comparing fatigue levels between inner city and suburban bus routes, or comparing fatigue between new and more experienced drivers. Further work is particularly needed to evaluate the effectiveness of the solutions proposed in this report.

Despite the limitations discussed, the current research is extremely important as it greatly increases our knowledge on fatigue/ sleepiness amongst bus drivers, and our awareness of the associated safety issues. Bus drivers are an understudied group within research relating to fatigue. The research presented in this report is the first of its kind to investigate bus driver fatigue so widely, by using a combination of research methods (including the first on-road investigation of its kind), this work has clearly demonstrated that sleepiness/ fatigue needs to be considered in the context of London bus drivers.

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1 Introduction

1.1 Background

Transport for London (TfL) put out a call for tender to investigate the prevalence of fatigue amongst London bus drivers, to which Loughborough University and The Swedish National Road and Transport Institute (VTI) responded. The aim of this work is to understand if fatigue is a problem for London bus drivers, and if so, investigate the nature of this problem and propose solutions. To achieve this, the following research questions were addressed:

1. What is the extent and nature of fatigue in London bus drivers?
2. What are the key causes of fatigue? Are there patterns of working, demographics or any other factors that are correlated with fatigue in London bus drivers?
3. Based on the findings to questions 1 and 2, what solutions should we be implementing or trialling to reduce fatigue and the risk of associated incidents?
4. How effective are these solutions at reducing fatigue and by extension, fatigue related collisions or safety incidents?

A programme of 6 research tasks were undertaken in order to achieve the stipulated project brief. These were followed by a discussion of the potential solutions based on the findings. The 6 research tasks were:

- Task 1: Literature review
- Task 2: Internal policy review
- Task 3: Focus groups with bus drivers
- Task 4: Manager interviews
- Task 5: Driver survey
- Task 6: On-road observation

This document is the final report at the end of the project timeline. This report contains the finalised methodology, findings, and recommendations for potential solutions based on these findings. The report will also discuss some potential avenues for future research.

1.2 Project scope

This project is investigating fatigue/sleepiness amongst London bus drivers. Wherever possible, all 10 bus operating companies (excluding 'Dial a Ride') are included.

Within the project, driver fatigue is considered to be a psychological and/or physical impairment experienced by a driver (either subjectively or objectively) which has the potential to reduce optimal performance. Drivers experiencing fatigue may invoke strategies and resources in attempt to mitigate the effect. Specifically, fatigue will be considered to be multifaceted, encompassing pressures from both endemic sleepiness related to human biology, and task related fatigue. The considered facets are:

- Sleepiness due to insufficient sleep and/or time of day. This includes the circadian[1] and homeostatic[2] pressures all people suffer from and experience, and the added pressures resulting from shift work.

[1] Our circadian rhythms are biological processes displaying a near 24-hour cycle driven by an internal body clock, with peaks and troughs occurring throughout the cycle.
[2] Homeostatic pressure is a process which builds over time telling us that we have been awake for too long and that it is time to sleep.

- Task related fatigue due to the nature of work driving a bus in city environment resulting in an inability to continue, or impairment in performance caused by
    - Time on task due to the same activity going on too long.
    - Overload of cognitive demands during times of exposure to demanding workload. This element this is strongly interrelated with stress.
    - Underload of cognitive demands during times of monotonous activity.
    - Physical muscle fatigue due to physical exertion, for example, steering the bus.

Stress is a multifaceted concept, in this project we look at driver stress both in terms of an adaptive physiological response that mobilises the body's energy reserves to face everyday challenges but also as a subjective feeling of not having enough resources to meet the demands of one's environment. Stress is a continuum; extreme stress has the potential to lead to mental health conditions, however, it should be noted that this was not the direct focus of stress within the context of this report.

In several research tasks, drivers were directly asked about, or referred to, stress. These instances are referred to this as self-reported stress. In some of these cases, drivers used the word stress to refer to other experiences. In these instances, phrases such as mental/ cognitive overload, workload, or pressure are used to indicate the specific experience being described.

1.3 Structure of the report

This report begins by describing the methodology used in each of the research tasks (section 2). The next section (3) discusses the findings from research tasks 1-6, as well as considering some implications from each individual set of findings. Section 4 presents the proposed solutions which were formed based on the results of the previous research tasks. Finally, section 5 discusses some of the limitations to the current research, and presents suggestions for further work.

2 Methodology

The research tasks undertaken in this project received full ethical approval from Loughborough University (HPSC Reference Number: C16-62).

2.1 Task 1: Literature review

Search Approach

A systematic search was conducted, extracting scientific literature relating to bus driver fatigue from published journal and conference articles, government and non-government reports, and other bus driver fatigue-related literature. Throughout the literature and within occupational settings, the terms “fatigue” and “sleepiness” are generally used interchangeably, however, within the scientific literature there is usually a distinction between the two. Whereas “sleepiness” is defined as the physiological urge to fall asleep, usually resulting from sleep loss (Dement & Carskadon, 1982), “fatigue” has been defined as the inability to continue a task or activity because it has been going on for too long (Bartley & Chute, 1947), this includes both overload and underload situations (May & Baldwin, 2009).

Four databases (*SafetyLit*, *Scopus*, *Pubmed,* and *TRID)* and Google Scholar were reviewed. The search for bus driver specific papers was restricted to documents published within the last 12 years, and which included at least an English abstract. The search was conducted using the following terms: “bus driver”, or “coach driver”, and “fatigue”, “sleepiness”, “drowsiness”, and “tiredness”, across different databases to maintain consistency.

In total, only 26 papers were identified that were specific to bus driver fatigue, highlighting that fatigue within this population is currently an under researched area. A summary table of these documents is provided in Appendix A.

Scope

The focus of this literature review is to identify the documents relevant to bus driver fatigue and sleepiness. Due to the limited results specific to bus drivers, research findings relating to fatigue in other professional and non-professional drivers have also been considered. The identified literature was considered from two perspectives: firstly, to understand the context of fatigue (extent, nature, and causes), and secondly, to understand the evidence for solutions to manage bus driver fatigue.

2.2 Task 2: Internal policy review

Two approaches were employed to review fatigue policies within the 10 London bus operators: (1) a questionnaire requesting general details about each operator and (2) a request for details of the operator’s policy for fatigue management. Respondents to the questionnaire were free to complete this without input from the researchers. Operators who do not have a formal fatigue management policy were asked to provide other policy documents which have any content relating to fatigue management, for example, driver handbook, fitness for work rules and so on. This was not a review of the documents which each operator actually had, but rather the documents they believed they had in relation to driver fatigue. The review of each individual operator’s internal fatigue management policy was conducted in order to compare the similarities and differences of approach between the London bus providers. Prior to the completion of the policy review, respondents were sent a list of documents received in this context, and were asked to confirm that these were correct.

2.3 Task 3: Focus groups with bus drivers

Driver discussion groups were held to explore the experiences of fatigue when bus driving. The groups were intended to investigate the issues which bus drivers find significant in relation to fatigue. A focus group discussion guide of questions and prompts was developed to ensure each group followed the same format (see Appendix B). The focus group guide was informed by issues identified during the literature review and the prior knowledge of the researchers, with the aim of answering the following questions:

1. Do bus drivers believe fatigue/sleepiness to be a problem in their industry?
2. How is fatigue/sleepiness managed at work?
3. How do problems like stress and threats/violence contribute to driver fatigue?

2.3.1 Participants/ recruitment

The research study contact person at each operator was contacted by e-mail and asked to assist with the focus groups by identifying a suitable depot or garage and the relevant contact who is based there. A group of 6-8 drivers to include experienced drivers, with a balanced mix of those who have been employed long-term together with those having been driving for a shorter period (but for at least one year) were then invited to attend the discussion. The researchers also requested that a room be made available which was suitable in size and privacy for the discussion.

2.3.2 Procedure

At the beginning of each group, drivers were provided with an information sheet explaining the background to the research and providing contact details of the research team. Participants were then asked to sign an informed consent form which included details about the recording of the discussion. Basic (anonymous) demographic data was also collected from the participants in a very short questionnaire. The participating drivers were encouraged to treat the experience as an informal discussion about their experiences of fatigue and how it is managed at work, and to express their honest opinions. It was stressed that the research (and therefore the discussion) is really important for future fatigue management in the industry. Drivers were urged to talk to each other and to the researchers during the discussion and thereby share experience. It was emphasised to participants that all information they provided would be confidential, with no individuals or operators being identified in any reports.

The data collection took place in October and November 2018 at a London bus depot or garage nominated by the operator. The discussion occurred in a private room where it could not be overheard by anyone outside and no managers were present. Focus groups were facilitated by two researchers, with one consistent individual being present at all of the groups and undertaking the three driver interviews.

2.3.3 Analysis

The discussions were audio recorded, transcribed and analysed using a thematic approach allowing themes to develop both from the research questions and from the narratives of the participants. The themes were discussed and devised by two researchers.

2.4 Task 4: Manager interviews

A total of 11 one to one telephone interviews with a range of managers were conducted. The manager interviews followed on from the bus driver focus groups to determine whether a mismatch exists between how drivers are managing fatigue and how managers believe that fatigue is being managed. The data collection took place in November 2018.

2.4.1 Participants/ recruitment

The research study contact person at each operator was contacted by e-mail and asked to assist with the manager interviews by identifying a suitable manager or supervisor to be interviewed. Participants were defined as 'A person who directly supervises drivers and discusses issues encountered during driving'. The participants were therefore a selection of immediate driver supervisors and higher-level managers within the bus companies.

2.4.2 Procedure

A manager interview question guide was produced in order to ensure each interview followed a similar format (see Appendix C). The guide arose from the findings of the literature review, the bus driver focus groups, and the prior knowledge and experience of the researchers. The manager interview question set was specifically designed to explore managers' views of fatigue, their perception of the causes and consequences, strategies to manage fatigue and their experience of fatigue in driving incidents. The interviews explored the understanding of fatigue and sleepiness in the industry, its effects, and how it is managed.

2.4.3 Analysis

The interviews lasted 30-45 minutes and were audio recorded, transcribed and analysed using a thematic approach allowing themes to develop from the research questions, the results from the focus groups and from the narratives of the participants.

2.5 Task 5: Driver survey

2.5.1 Procedure

All drivers working for the 10 London bus operating companies were eligible to complete the driver survey. The survey was developed to identify the prevalence of fatigue and identify factors which lead to experiencing fatigue. The survey was available to complete online or in paper format. Primarily, the survey was distributed by a link to the online version (through emails, letters, and posters or business cards containing a QR code).

The survey questions covered the following topics:

- How prevalent is driver sleepiness?
- How do background factors such as age, gender, socioeconomic factors, but also type of employment contribute to driver fatigue/sleepiness?
- What working and health conditions are associated with severe driver sleepiness?

The core questions were translated from the Swedish 35 item questionnaire designed and used to measure fatigue in Swedish bus drivers (Anund, Ihlström, Fors, Kecklund & Filtness, 2016). Additional questions were added which arose from the prior knowledge and expertise of the researchers, as well as the responses from the focus groups. The survey was split into five sections: (1) questions about your work as a bus driver, (2) questions about your sleep, (3) questions about your health, (4) questions relating to yourself as a bus driver, (5) background questions. The full list of survey questions can be found in Appendix D.

2.5.2 Analysis

The survey was open to respondents for three months. Two types of analysis were conducted: (1) general descriptive statistics to explore the extent and nature of bus driver fatigue, and (2) logistic regressions to determine which factors significantly predicted fatigue.

Within the regression analyses relating to sleep, there are 5 sleep indexes which have been entered as predictor variables. As part of the survey, drivers were presented with 20 statements related to sleep and were asked to "indicate the degree to which the following have happened to you during the last 3 months". Drivers responded to each statement with one of six options ranging from "never" to "always (5 or more times a week)". All indices (apart from the fatigue index) were part of the Karolinska Sleep Questionnaire (KSQ) as used by Anund et al. (2016). Based on these responses a numerical average was calculated for several statements to form each of the 5 sleep indexes, as follows:

- **Sleep quality index**: difficulty falling sleep, repeated waking, waking up too early, disturbed or worried sleep
- **Sleepiness index**: feeling sleepy at work, feeling sleepy during leisure time, fighting to stay awake throughout the day, involuntary falling asleep at work, involuntary falling asleep during leisure time
- **Fatigue index**: physical fatigue, mental fatigue
- **Impaired waking index**: difficulty in waking up, not feeling alert on waking up
- **Suspected sleep apnoea index**: snoring, difficulty catching your breath whilst sleeping, interrupted breathing during sleep

2.6 Task 6: On-road observation

The on-road observation used an explorative design to understand fatigue during normal bus driving. Tasks 1-5 were designed to collect a wide range of information across all operators; in contrast Task 6 was designed to obtain detailed information from a small group of drivers employed by one operator.

All operators were eligible to volunteer to participate in the on-road observation. A document explaining the intended study design was circulated, and three operators expressed interest. Individual discussions were held with each operator detailing the requirements and logistical limitations for both the research design and business operations. Following these discussions one operator was selected to participate in this task.

The on-road study was designed to examine fatigue in normal driving operations using physiological and vehicle recording metrics. It was important that the design allowed the investigation of specific research questions but did not compromise the delivery of service for the operator. The design features were informed by the literature review, focus groups, preliminary survey findings, and the prior expertise of the research team.

2.6.1 Participants/recruitment

A total of 16 drivers were included in the study (mean age 46 years, range 35 to 57 years). Volunteers were recruited among drivers scheduled to work the selected bus route during the study period.

The inclusion criteria were:

- Working as a bus driver on a regular basis
- Working as a bus driver for at least 2 years
- Not being on sick leave for more than 3 days in the last 2 months
- Agreeing to wear electrodes and to be recorded
- Agreeing to use an actigraph and complete sleep diaries in the days before the study

2.6.2 Procedure

Bus drivers working on a Central London bus route were observed whilst driving on the same route twice, once in an expected alert condition and once in an expected fatigued condition. The bus was in service for both of the conditions. The selection of alert and fatigue conditions were based on the survey and focus groups results from other data collections within the project, where it was found that drivers perceived the morning shift to be more fatiguing than the daytime shift. Daytime driving (start after 9am) was therefore used as the alert condition, whereas morning driving (start before 7am) was used as the fatigue condition. Before the on-road data collection started, the drivers were invited to a preparation meeting at the bus depot. They were informed about the study and were familiarised with the equipment used for physiological monitoring and the subjective scales of sleepiness and stress. After giving their informed consent to participate, the drivers received sleep monitors (actigraphs), a sleep and wake diary, and a background questionnaire. Four days before each drive, the participants wore actigraphs and filled in the sleep and wake diary to keep track of their sleep/wake history.

On the day of the data collection the test leader met the bus driver at the depot and followed them to the bus. The test leader briefed the bus driver about what was going to happen during the drive and when everything was clarified the driver was asked to sign an informed consent form.

Thereafter, the bus driver was equipped with the physiological measurement equipment. This was completed either at the depot or in the bus depending on if it was a morning or day shift.

The test leader rode the bus during the drive and data collection was started when the bus reached one of the end stations of the selected bus route. Data collection continued until the driver reached the other end of the route.

The drivers were instructed to drive as they normally would and not change anything about their normal driving. Every five minutes during the drive, the drivers verbally reported their level of sleepiness and stress (see section 2.6.3.3).

After the drive, the electrodes were removed, and the participants answered questions about their experiences during the drive.

2.6.3 Self-reported data

2.6.3.1 Background questionnaire

All participants completed the background questionnaire which was a slightly modified and shortened version of the survey (see section 2.5 and Appendix E). It comprised questions about demographics, sleep, working conditions, health and bus driving. The questionnaire also included the Karolinska Sleep Questionnaire [KSQ] (Nordin, Åkerstedt & Nordin, 2013) to assess sleep quality. Subjective sleep quality was assessed on five indices (see section 2.5.2).

2.6.3.2 Sleep and wake diary

Four days before both the 1st and 2nd experimental day, the participants started to fill in sleep and wake diaries. The diaries included questions about night sleep (sleep quantity, sleep quality and sleeping problems), to be answered upon waking, and questions about fatigue and experiences during the day, to be answered at bedtime.

2.6.3.3 Sleepiness and stress ratings

The level of subjective sleepiness during each drive was assessed by using the Karolinska Sleepiness Scale [KSS] (Åkerstedt & Gillberg, 1990). Individuals were required to indicate on a nine-point scale

how sleepy they had felt (1 = extremely alert to 9 = very sleepy, great effort to keep awake, fighting sleep) on average during the previous 5 minutes.

Subjective stress level was assessed using the Stockholm University Stress Scale [SUS] (Dahlgren, Kecklund & Åkerstedt, 2005), which is a nine-point scale ranging from 1= Very low stress (I feel very relaxed and very calm) to 9= Very high stress (I feel very tense and pressed – at the limit of what I can stand). This was also reported as an average for the previous 5 minutes.

Every five minutes during the drive, the participants were prompted with a beeping sound to report sleepiness and stress into the microphone. They were instructed at the start of each drive to first give the rating for sleepiness and thereafter the rating for stress level. These verbal ratings were audio recorded.

This method has been used in previous on-road investigations (Anund, Fors, Ihlström & Kecklund, 2018) and did not have a negative impact on driver safety. Drivers were also informed that if for any reason they were unable to report their sleepiness or stress (such interacting with passengers or traffic controllers) then they should skip this reporting and continue after the next beep. All testing protocols were subject to Loughborough University ethical procedures which includes a risk assessment.

2.6.3.4 After driving questionnaire

The bus drivers' experiences from the drive were captured with help of questionnaires after the experiment. The questionnaire consisted of 10 questions and encompassed topics of sleepiness, stress, worry, if control was lost during the drive and if any countermeasure were used to stay awake. The questions were both of scale type as well as free text answers. The ratings were given on a scale from 1 to 7 or 1 to 5 where 1 was lowest and 7 or 5 the highest problems, see Appendix F.

2.6.4 Actigraphy

Four days before both the 1st and 2nd experimental day, the participants started to wear the actigraph (MotionWatch, CamNTech Ltd, Cambridge, UK). The actigraph was worn around the non-dominant wrist like a watch and recorded movement (see Figure 2.1). The face of the "watch" was blank, it did not provide any information or distraction to the driver during participation. Participants were instructed to wear the actigraph day and night, except when bathing or showering.

The participants were instructed to press an event marker button on the actigraph every time they went to bed ('Lights Out') and woke up ('Got Up'). This was done for night sleep and for daytime naps. 'Lights Out' and 'Got Up' times were manually checked and compared against the sleep diaries. Sleep analysis was done using MotionWare software. For each sleep period, the following measures were analysed:

- Total sleep time (TST); the total time spent in sleep according to the sleep analysis.
- Sleep efficiency (SE); the total sleep time expressed as a percentage of time in bed (the total elapsed time between the 'Lights Out' and 'Got Up' times).
- Sleep onset latency (SOL); the time between 'Lights Out' and the time point of falling asleep as identified by the sleep algorithm.

Statistical analyses were performed on sleep measures from the night before each drive as well as on mean TST, SE and SOL of the four days before each drive. Naps were included in the calculation of four-day averages.

Figure 2.1: Actiwatch

2.6.5 Physiological measurements

Heart rate and eye blinks were collected using a Vitaport 3 system. Electrodes were placed mainly on the right side of the face, which was facing away from the passengers, and on the body (see Figure 2.2). For the purposes of statistical analyses, heart rate variability (HRV) will be reported. The main idea is that increased heart rate and reduced heart rate variability is an indication of increased stress, whereas reduced heart rate and increased heart rate variability is an indication of sleepiness/fatigue. A more detailed description of the physiological measurements can be found in Appendix G.

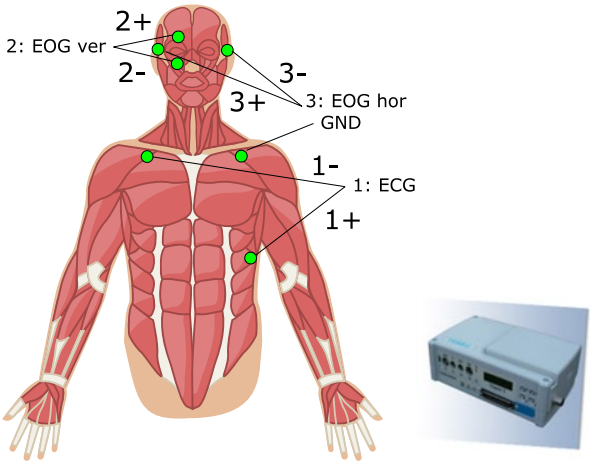


Figure 2.2 Electrode placement and the Vitaport

2.6.6 Driving data

The buses were equipped with a Vbox (Racelogic Ltd, Buckingham, UK), cameras, GPS and a microphone for measurements of driving related data and drivers self-reported sleepiness and stress levels. Two cameras were installed, one facing forward and one facing the driver (see Figure 2.3).

Speed, acceleration, and deceleration data were averaged in five-minute intervals for each drive (described in the unit m/s^2). Geographical position was used to code each five-minute interval into one of five pre-defined zones along the bus route. The two systems were synchronised with a time stamp.

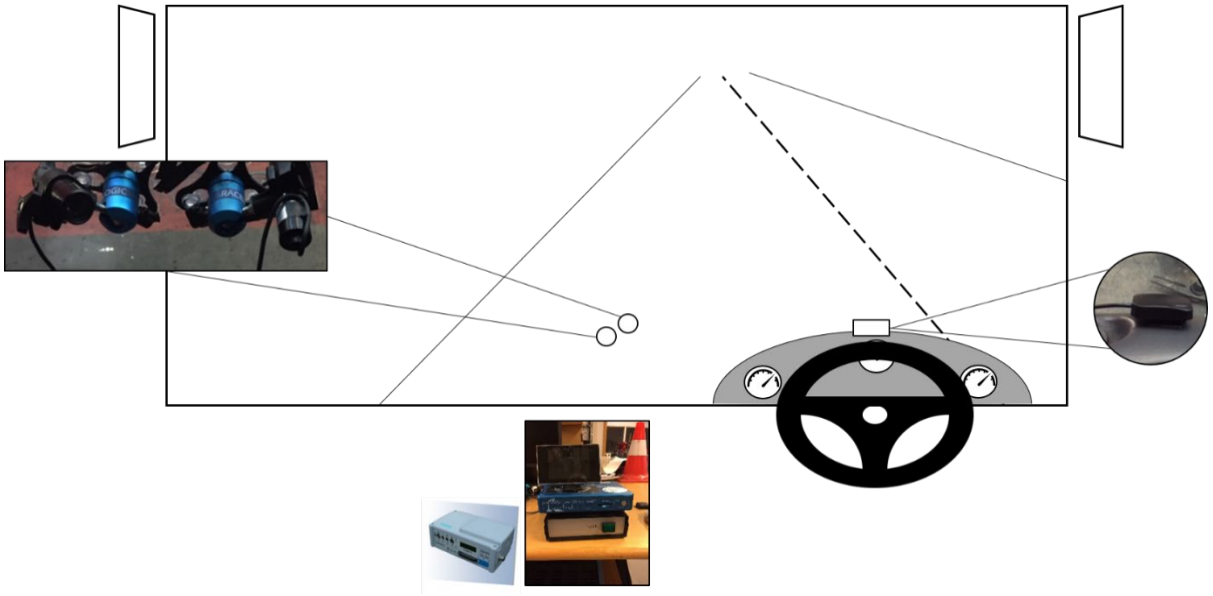


Figure 2.3 The bus set up for the on-road study. Two cameras were attached to the windscreen (one facing the driver and one facing the road) in a location which would not obstruct the drivers view. The GPS antenna was attached to the top of the instrument cluster. The vbox, vitaport and beeper phone were placed out of view of the driver in a small storage compartment to the lower left of the steering wheel.

2.6.7 Statistical analysis

Statistical comparisons were made between the results from the sleep and wake diaries and the actiwatches for rest days, morning shifts and daytime shifts. Statistical comparisons were also made between several physiological and behavioral variables from the early morning and daytime drives. Further details of these statistical analyses can be found in Appendix G.

3 Key findings

3.1 Task 1: Literature review

3.1.1 Key findings

3.1.1.1 Overview of Fatigue - the Extent and Nature of Driver Sleepiness

Driver fatigue is a globally known causation factor contributing to road traffic accidents, injuries, and deaths in various transportation operations (Williamson et al., 2011; Bioulac et al., 2017; Zhang, Yan, Wu, & Qiu, 2014). Although there are various definitions of fatigue, certain features such as subjective sleepiness, changes in psychological state, decrements in performance, reduced alertness, and difficulties with sustained attention, can be used to characterise fatigue (Williamson, 2007). For the purpose of this review, driver fatigue is considered to be "*a psychological and /or physical impairment which has the potential to reduce optimal performance. Fatigue is considered to be multifaceted, encompassing pressures from both endemic sleepiness relating to the body's homeostatic and circadian pressures, and task related fatigue".* Regardless of specific vehicle types, research has shown that 27% of drivers have experienced difficulty keeping their eyes open while driving within the past month, and 41% of drivers admitted to falling asleep behind the wheel at least once in their lifetime (Tefft, 2010). In relation to professional drivers, these figures are increased, as 38% of drivers have experienced fatigue at least once per week, and 45% of drivers reported nodding off whilst driving in past 12 months (Friswell & Williamson, 2008). Furthermore, in a study on Swedish city bus drivers, more than 40% reported fighting to stay awake while driving at least 2-4 times a month, and 19% had to fight to stay awake at least 2-3 times a week (Anund et al., 2016) (the results of this study are discussed further in relation to the driver survey in section 3.5)

Fatigue is thought to be a contributing factor to approximately 15% to 30% of road traffic crashes globally (Connor et al., 2002; Horne & Reyner, 1995; Phillip et al., 2014). However, there are difficulties associated with measuring fatigue after a crash takes place. Where specific effort is put in to train police officers to identify fatigue, estimates are higher than when relying on standard police recording (Horne & Reyner, 1995).

Research has shown that one of the main causes of fatigue related transport incidents are attentional lapses due to insufficient sleep (Philip & Åkerstedt, 2006; Philip et al., 2005; Schwarz et al., 2016). Several other factors can also result in fatigue, including insufficient or lack of sleep, extended or prolonged wakefulness, disruptions to circadian rhythms, and sleep disorders (Zhang et al., 2014). External influences such as time spent on task can also impact fatigue (Williamson, 2007).

Fatigue risk management has become an important component of health and safety within occupational settings, however the varying definitions of fatigue (Phillips, 2015) (as previously mentioned) can result in varying interpretations. For instance, fatigue could occur from engaging in both simple tasks for long durations, such as monotonous long-distance driving, as well as highly complex short duration tasks, such as difficult city driving due to cognitive overload (May and Baldwin, 2009). Another factor to consider is the state of the driver at the start of their driving duty, as this will likely impact fatigue and sleepiness. For example, a bus driver who suffers from a sleep disorder or poor or disturbed sleep may begin their duty with a high level of sleepiness, even if the duty begins soon after waking or during times of peak alertness, and an individual who has an additional job may experience cumulative fatigue from previous activities. Fatigue and sleepiness are important factors related to safety, and both should be considered in terms of fatigue risk management.

Driver sleepiness research is an important and current topic. For example, in 2015 in the U.S, a panel of sleep science experts, traffic safety, legislators, vehicle manufacturers, federal representatives, insurance groups, advocacy groups, and public and work safety groups convened to build consensus on research, programme, and policy objectives to address risks, consequences and countermeasures related to drowsy driving (Higgins et al., 2017). The panel highlighted issues with the extent of fatigue as a problem in driving and in crash investigating and reporting. It is difficult to accurately assess the impact of fatigue-related issues solely through the crash data. This is due to the fact that crash data only highlights those who have experienced or reported an accident or incident in which fatigue was a contributory factor, whereas many people suffering from the effects of fatigue possibly are not involved in crashes or incidents. The panel stressed the need for ongoing research to understand people's knowledge, attitudes, and behaviours in relation to driver sleepiness. There have been recent attempts to work on this, for example research in Sweden led to the refinement of crash checklists for police officers to complete upon arriving at road accidents. Results highlighted the issue of sleepiness in relation to driving and road accidents, the need for routines and tools to identify driver sleepiness, and for officers to be adequately trained in such techniques and ensure the time to complete any sleepiness checklists (Anund, 2008; Gertler, Popkin, Nelson, O'Neil, 2002).

Previous research has shown that driving while fatigued results in decrements in performance for both simple and complex tasks, impaired attention, slowed reaction times, and loss of conscious awareness while behind the wheel (see Williamson et al., 2011 for review). The implications of this have been demonstrated in both studies on real roads (using naturalistic and experimental approaches) and simulator studies. A recent analysis of research relating to sleepiness and motor vehicle accidents, including 17 papers with over 70,000 participants, found that the risk of motor vehicle accidents more than doubled due to sleepiness at the wheel (Bioulac et al., 2017). Fatigue also results in a higher rate of lane crossings (Filtness, Reyner, & Horne, 2012; Hallvig et al., 2014), reductions in hazard perception (Smith, Horswill, Chambers & Wetton, 2009), and an increased tendency to become distracted (Anderson & Horne, 2013). It has also been found that extended wakefulness results in neurobehavioral impairments similar to those found following alcohol consumption (Watling, Armstrong & Smith, 2013), with research indicating that driving performance after 17 hours of wakefulness (Dawson & Reid, 1997), or after nocturnal driving of two hours (Verster, Taillard, Sagaspe, Olivier & Phillip, 2011), is equivalent to a blood alcohol concentration (BAC) of 0.05%. In the U.K., the legal driving limit for BAC is 0.08%, in Scotland and most EU countries, the legal limit is a BAC of 0.05%.

There are links between time of day and driving incidents, with the highest number of crashes or incidents occurring during times when alertness would be at its lowest due to our circadian rhythms (Åkerstedt, Connor, Gray & Kecklund, 2008; Connor et al., 2002; Garbarino, Lino, Beelke, Carli, & Ferrillo, 2001; Horne & Reyner, 1995; Milter et al., 1988). Our circadian rhythms are biological processes displaying a near 24-hour cycle driven by an internal clock, with peaks and troughs occurring throughout the cycle. These rhythms influence several behavioural, physiological and metabolic functions, including body temperature, and alertness. The lowest points of the circadian rhythm produce the strongest drive to sleep, with alertness beginning to decrease in the late evening, and reaching its lowest point between 02:00 and 04:00. An additional, smaller dip in alertness is also experienced in the early afternoon between 13:00 and 15:00.

Sleepiness risk in relation to driving is often underestimated, and certain occupations have been found to have an increased risk of crashes or near misses from sleep loss, including shift workers, (Colquhoun, 1976; Di Milia et al., 2011; Folkard & Monk, 1979; Gold et al., 1992; Richardson, Miner & Czeisler, 1990; Stutts, Wilkins, Osberg & Vaughn, 2003) truck drivers (Lyznicki, Doege, Davis &

Williams, 1998; McCartt, Rohrbaugh, Hammer & Fuller, 2000; Stoohs, Guilleminault, Itoi & Dement, 1994), and professional drivers (Bunn, Slavova, Struttmann & Browning, 2005). Compared to non-professional driving, certain aspects of professional driving are risk factors for fatigue including a sedentary and restricted posture, long hours of driving, irregular shift patterns, and a unique work environment (Bunn et al., 2005; Chaiard, Deeluea, Suksatit & Songkham, 2019; Öz, Özkan & Lajunen, 2010). Typically, irregular working hours (Wilson, Chattington & Marple-Horvat, 2008), night shifts (Barth & Franke, 2009; Bella & Calvi, 2013; Chaiard et al., 2019; Stanton & Young, 1998; Wilson et al., 2008), extended shift duration (Barth & Franke, 2009; Bella & Calvi, 2013; Stanton & Young, 1998), reduced sleep (Stanton & Young, 1998), high work load (Stanton & Young, 1998), early morning shifts (especially in combination with monotonous driving) (Barth et al., 2009; Bella & Calvi, 2013; Thiffault & Bergeron, 2003ab), and low task demand (Dunn & Williamson, 2012), are contributing factors to fatigue, many of which are regularly experienced by drivers. It might be thought that professional drivers are more capable of staying alert compared to non-professional drivers, however this is not the case (Anund, Ahlström, Fors & Åkerstedt, 2018). Professional drivers self-reported being more alert, but more objective measures show greater sleepiness and more involuntary lane crossings compared to non-professional drivers.

3.1.1.2 The Key Causes of Driver Fatigue Relevant to Bus Drivers

Bus driver fatigue has typically received less attention (Tse, Flin & Mearns, 2006), as the majority of sleepiness research has previously been conducted with non-professional drivers (Åkerstedt et al., 2013; Hallvig et al., 2013; Sagaspe et al., 2008), or truck drivers (Hanowski, Wierwille, & Dingus, 2003; Kecklund & Åkerstedt, 1993; Mitler, Miller, Lipsitz, Walsh, & Wylie, 1997). Fatigue in relation to bus drivers has sometimes been considered under the category of heavy goods vehicles (HGVs) (Biggs, Dingsdag & Stenson, 2009), however, the driving styles and environments of drivers of HGVs and buses are significantly different.

The limited available research has indicated that sleep loss is a major issue for city bus drivers, with approximately 45% of Swedish bus drivers having to fight against sleepiness at least 2-4 times each month whilst driving the bus, and 19% of drivers fighting to stay awake at least 2-3 times per week (Anund et al., 2016). A previous study conducted in Edinburgh found that 20% of bus drivers reported excessive daytime sleepiness, reporting scores of more than 10 on the Epworth Sleepiness Scale (ESS), a subjective scale designed to assess trait daytime sleepiness. Respondents are asked where they rate on a 4-point scale (0-3) their usual chances of falling asleep or dozing off during eight different activities. The ESS score can range from 0-24, with scores of 10 or more being associated with excessive daytime sleepiness. 12% of drivers were also found to have fallen asleep at the wheel at least once per month, 7% had had been involved in an accident and 8% of drivers had experienced a near miss due to sleepiness while driving (Vennelle, Engleman, & Douglas, 2010).

Bus driver fatigue is not solely a European issue, with reports of fatigue and sleepiness levels, accidents and near misses, occurring frequently in Peruvian bus drivers (Deza-Becerra et al., 2017; Liendo, Castro & de Castro Rey, 2010). Questionnaire data has shown that 74% of bus drivers experienced fatigue, 25% of drivers experienced sleepiness, and 35% of drivers reported ‘nodding’ while driving (Deza-Becerra et al., 2017). The studies also highlighted the reduced sleep obtained by bus drivers, with 9% of drivers sleeping less than six hours per day (Deza-Becerra et al., 2017), and approximately half (43% of informal drivers and 48% of formal drivers) of drivers reporting sleep of less than seven hours a day (Liendo et al., 2010). Under sleeping is also prevalent amongst bus drivers working early morning shifts as actigraph data shows that they do not go to bed early enough to get sufficient sleep before the next days early morning shift (Diez et al., 2011). As sleep loss and being awake for too long are contributing causes of driver fatigue (Åkerstedt, Connor, Gray &

Kecklund, 2008), reduced sleep and inadequate rest are important issues to consider. Self-report data has also shown instances of poor sleep quality, insomnia, and increased risk of obstructive sleep apnoea (OSA), as risk factors associated with excessive daytime sleepiness in Korean bus drivers (Kim et al., 2017), with 13.2% of questionnaire respondents reporting ESS scores of more than 10, 68.4% of drivers experiencing poor sleep quality, and 10.2% of drivers reporting moderate to severe insomnia.

3.1.1.2.1 Shift Schedules and Irregularity

Long working hours have been shown to contribute to increased sleepiness and increased crash risk (Robb, Sultana, Ameratunga, & Jackson, 2008), particularly when combined with sleep loss, lack of breaks, and difficult working conditions (Pylkkönen et al., 2015), all of which bus drivers are likely to experience. Scheduling affects drivers directly, impacting their sleep opportunities, rest breaks, and length of working. The added passenger and traffic elements can potentially result in reduced breaks and extensions of driving time, both of which are factors related to fatigue. The literature search identified 10 studies which directly considered shift work pattern and bus driver fatigue.

Bus driver shift pattern scheduling has also been shown to impact crash risk (Wang & Wu, 2019), with research conducted in Malaysia reporting that bus accidents were significantly related to work schedule (Abdullah & Von, 2011). Research exploring fatigue variables reported that one of the main contributing factors of driver fatigue was unrealistic scheduling (Biggs, Dingsdag & Stenson, 2006), which was supported by further research identifying nine causation factors of fatigue, several of which were related to work schedule: tight route schedules, turn-around and shift irregularity, and extended shift cycles (Biggs et al., 2009).

Split shift working (or spreadovers), involves dividing the work duty into two parts, with a long break (> 2 hours) in between often to meet the needs of commuters. Long working hours and insufficient sleep have been found to be associated with split shifts (Anund et al., 2016; Sando, Mtoi, & Moses, 2010), with objective evidence of increased sleepiness during the afternoon in those drivers who had previously worked a morning shift, compared to those who had been off duty (Anund et al., 2018). However, subjective data has shown that in general, split shift working is not associated with detrimental health and psychosocial issues, and that only the drivers who stated problems with split shift working reported poorer health, increased stress, interference with social life, reduced sleep quality, fatigue, and lower work satisfaction (Ihlström, Kecklund, & Anund, 2017). The added issue with split shift working is what drivers decide to do or can do on their break, determined by break length, commute times, and available facilities. A study found that a small number of bus drivers relaxed or napped either at work or at home during their rest break. However, a larger number of drivers engaged in various activities during their break, including non-driving duties, eating, shopping, attending appointments, and reading (Sando et al., 2010). Differences in self-reported sleepiness levels for bus drivers on differing schedules have also been shown (Lee, Kim, Byun, & Jang, 2017). Alternating day shift workers, who displayed characteristics of irregular shift patterns and extended working, suffered from increased sleepiness compared to daily split shift bus drivers.

3.1.1.2.2 Regulation, Tight Route, and Night Schedules

Regulations can be put in place to specify a required maximum shift and minimum break duration; Table 3.1 shows the driving hours and regulations, as specified by the Vehicle Operator Services Agency [V.O.S.A] (2015), for both Great Britain and the European Union.

Table 3.1: Drivers' hours and regulations

	GB Domestic	EU rules
Daily driving limit	10 hours	9 hours (this can be increased to 10 hours twice a week)
Maximum continuous driving	5½ hours, then 30-minute break	4½ hours, then 45-minute break
Maximum spreadover	16 hours	13 hours (or 15 hours up to 3 times a week)
Minimum daily rest	10 hours (can be reduced to 8½ hours up to 3 times per week)	11 hours (can be reduced to 9 hours up to 3 times a week)
Weekly limits		56 hours maximum driving
Fortnightly limits	Must include 1 rest day	90 hours maximum driving

Driving hour regulations are complicated by overlapping jurisdictions. For example, drivers of passenger vehicles in the UK should follow the EU regulations outlined in Table 3.1. However, London bus drivers (along with most urban bus drivers) fall into an exemption category within the EU rules as buses do not travel routes longer than 50km. Therefore, the GB domestic rules apply.

There is also no central regulation or requirements on fatigue risk management. Each independent operator may develop and follow their own procedures for fatigue management including fatigue related accident and incident reporting and shift pattern design. From the literature search, seven studies were found that related to regulations, schedules and bus driver fatigue.

Bus drivers can face challenging tight route schedules, especially in the city centre during peak hours, which has been reported as a contributing factor to fatigue. Although schedules are designed to work the majority of the time, factors such as traffic, passengers, and headway can impact route timings. Since the delay margin for buses is small, time pressure is likely to be generated and accumulated, restricting turnaround times and breaks, and hence increase their overall stress level (Biggs et al., 2009). Another fatigue consideration is the complexity of the route. Although drivers' fatigue levels have been shown not to be affected by route type, a study found that certain fatigue symptoms (including yawning, wanting to lie down, and eye strain) were significantly higher following a complex city centre route (Makowiec-Dabrowska et al., 2015), compared to the 'easier' route outside the city centre. This coincides with the differences in task related fatigue discussed earlier, and work underload and overload.

Driving during the circadian low, for example night or early morning driving, is known to contribute to driver fatigue (Åkerstedt et al., 2008; Chaiard et al., 2019; Diez et al., 2011). There are reports of high incidences of night time sleepiness and daytime sleep disruptions in night shift bus drivers (Krishnaswamy, Chhabria, & Rao, 2016), with the most commonly reported time of day for being involved in, or almost having, an accident occurring between 01:00-04:00 (Liendo et al., 2010). In response to a number of bus crashes that occurred during the early morning in Malaysia, a proposal was put forward to stop the operation of buses during the early morning (00:00-06:00). However, unless other aspects of fatigue management were also addressed, such as poorly managed shift schedules and compliance with driving and working hours, it was concluded the full potential benefits would not be realised (Mohamed et al., 2012). Other instances of poorly managed schedules have been reported, with an increase in frequency of night driving (Liendo et al., 2010). For example, in Peru, 44% of formal bus drivers and 54% of informal bus drivers experienced five or more night shifts per week (Liendo et al., 2010), and 41% of the bus drivers drove seven nights per week, with 21% of drivers reporting they drove for more than five hours without a break (Deza-

Becerra et al., 2017). Research has also shown that drivers starting early morning shifts or finishing night shifts have an increased risk driving to or from home (Åkerstedt et al., 2008).

3.1.1.2.3 Working Conditions

Besides schedule design, the working conditions of bus drivers is also an important issue to consider in relation to fatigue. Five papers were found that addressed bus driver working conditions.

Both physical and psychosocial factors are known to contribute to the health and well-being of bus drivers, with some of these stressors including poor in-vehicle ergonomics, shift work, lone working, and risks of violence and intimidation, (Tse et al., 2006). Research has found that the condition of the bus is important, with indications that cabin ergonomics contribute to fatigue (Biggs et al., 2009), and that an improvement in overall bus condition would reduce accident rate (Abdullah & Von, 2011). In general, bus drivers may be exposed to heat, vibration, and noise due to bus design and road infrastructure, therefore leading to increased stress levels (Abdullah & Von, 2011; Biggs et al., 2009). City bus drivers potentially spend a large proportion of driving time sitting in congested traffic, facing time pressures, which could contribute to psychological stress, as well as stress related to the physical aspects of manoeuvring the bus (Ahlström, Gink Lövgren, Nilsson, Dukic Willstrand & Anund, 2018). Access to adequate driver facilities is also an important aspect, with reports of drivers sleeping in inappropriate places between shifts, detrimentally impacting sleep quality (Deza-Becerra et al., 2017). Stress is one of the strongest predictors of fatigue for city bus drivers, as are threats of violence and a lack of rest facilities (Anund et al., 2016).

3.1.1.3 Fatigue Countermeasures and Prevention Strategies for Bus Drivers

Countermeasures and prevention strategies for sleepiness in general, as well as in relation to driving, have received considerable attention over the past two decades. However, frequently used or popular countermeasures to sleepiness are not always available for bus drivers, who face a more restrictive working environment. Non-professional drivers, or long-haul truck drivers, can stop the vehicle and take a break if needed, possibly even nap, whereas bus drivers have strict time schedules to follow and are unable to take a break from driving whenever they would like. Even measures such as opening a window, or listening to the radio, which are frequently adopted by non-professional drivers (Gershon, Shinar, Oron-Gilad, Parmet, & Ronen, 2011), despite their ineffectiveness (Schwarz et al., 2012), are not availible to bus drivers. There are also limitations in terms of eating and drinking whilst driving, as well as the possibility that drivers face restricted access to facilities, potentially influencing their food and drink chioces. Additionally, in order to find effective countermeasures there is a need to understand the cause of fatigue (May & Baldwin, 2009). A bus driver that suffers from sleepiness can be helped by sleep and caffeine intake with some limitatons, on the other hand a bus driver suffering from fatigue due to overload may benefit from a change in activity or a short break.

Fatigue research and the evaluation of countermeasures has mainly been concerned with long haul, non-city driving, and is especially limited in relation to bus drivers. Fourteen papers were found that considered fatigue countermeasures and solutions for bus driver fatigue.

3.1.1.3.1 Education

Educating bus drivers on aspects of shift work, sleep, and effective countermeasures to sleepiness is an important prevention strategy, with research highlighting the need for educational interventions (Deza-Becerra et al., 2017), encouraging good sleep hygiene (Diez et al., 2011). Research conducted with night bus drivers in India focused on self-report coping practices and post shift sleep hygiene (Krishnaswamy et al., 2016), and showed that a range of strategies were employed by drivers to cope with nocturnal sleepiness, including consuming coffee or tea (16.7%), chewing tobacco (12.8%),

smoking (6.1%), and walking (3.9%). The paper concluded by highlighting the need for education relating to shift work, sleep hygiene and napping, as well as the controlled use of caffeine to promote wakefulness. Education surrounding the use of countermeasures was also recommended in terms of split shift working (Anund et al., 2018). A previous study concluded that attention needed to be focused on the occupational sleep hygiene of bus drivers, as well as emphasising the importance of sleep in relation to driving, and the treatment of sleep disorders within the bus driver community (Razmpa, Niat & Saedi 2011). Good sleep hygiene practices and overall health and well-being are important elements of shift work, with sleepiness a common risk factor for professional drivers. Studies have shown that body mass index (BMI) was correlated with sleepiness (Santos, Bittencourt, de Assis Viegas & Gaio, 2013), and that poor sleep quality, insomnia, and high risk of OSA, are three factors associated with excessive daytime sleepiness amongst bus drivers (Kim et al., 2017).

3.1.1.3.2 Scheduling

Several papers referred to the association between work schedules and bus driver fatigue, with suggestions of improved schedules possibly resulting in reduced accident rates (Abdullah & Von, 2011). It is important that a well-organised management system is developed, that allows enough recovery period for bus drivers (Machin & Hoare, 2008). Length of duty and work hours should also be considered, after it was found that reaction time in bus drivers decreased sharply after four hours of duty (Sang & Li, 2012), and that minimum rest periods may result inadequate time for rest and sleep (Sando et al., 2010). There have also been reports of cumulative fatigue increasing with the number of days and hours worked (Sando et al., 2010), and multi-day driving patterns are associated with higher crash risk (Wang & Wu, 2019). Schedule analysis can be aided by the use of biomathematical models. By rescheduling using an optimization model, research found that crash incidence could be reduced by approximately 30% (Wang & Wu, 2019), however the model used is theoretical in nature and dependent on probabilities, rather than a validated biomathematical model, therefore this figure should be interpreted with caution.

Consideration of working patterns is important, with reports of fatigue issues relating to split shift working (Anund et al., 2018; Sando et al., 2010). However, a previous study found that subjectively, split shift working only showed fatigue and psychosocial issues in those workers who reported problems working split shifts (Ihlström et al., 2017), possibly suggesting a more individual approach to shift patterns. However, individual preferences for roster schedules could also create additional issues relating to how individuals manage themselves, their rest, and their work pattern, and what their main motivation is for requesting a certain pattern. Restricting or stopping driving during times of the circadian low, for example during the night or early hours of the morning when alertness is at its lowest, could also impact fatigue related incidents, however this is possibly unrealistic in terms of 24-hour operations. This was suggested, as previously mentioned, in Malaysia to try and address the issue of increased crashes during these times (Mohamed et al., 2011), however it was concluded that a more holistic approach was needed, considering all aspects of road safety risk.

3.1.1.3.3 Fatigue-detection Technology

Advancements in technology have led to the development of certain fatigue-detection systems, aimed at helping drivers and operators detect and monitor fatigue states. The systems mainly function by collecting and measuring physiological outputs using a variety of measures, to produce information relating to driver fatigue. A vision-based fatigue detection system was proposed for use in bus driving, incorporating exisiting cabin cameras to measure a range of variables including face detection, eye detection, eye openess estimation, and percentage of eyelid closure, in order to predict the drivers fatigue state (Mandal, Li, Wang & Lin, 2017). Experimentally, despite the low

resolution images and the viewing angle, the system was able to distinguish between sleepy and drowsy states, and the normal driving state. Research has also suggested the use of EEG recordings to monitor the fatigue state of bus drivers (Wang & Wang, 2013). However, certain measurements, especially physiological measurements, may be considered to be intrusive, or even distracting. Systems also need to be monitored and interpreted, resulting in the need for additional time and possibily training and expertise. Devices have also been recommended to be installed into buses to detect fatigue-related decrements in driver performance (Sando et al., 2010). Although not suggested as a countermeasure to fatigue, research measuring fatigue in bus drivers utilised a range of performance tests including reaction time, speed perception, and attention (Sang & Li, 2012), which possibly could be incorporated into fitness for duty tests or an evaluation of driver state before, during, or after their duty period.

3.1.1.3.4 Bus Condition and Design

As it has been suggested within the limited literature that bus cabin ergonomics contribute to fatigue (Abdullah & Von, 2011; Biggs et al., 2009), an improvement of the overall road conditions and bus cabin ergonomics could be viewed as a relevant countermeasure, such as improvements to drivers' seats (Sang & Li, 2012). In terms of physical fatigue and driving, a study focusing on steering systems showed that additional features such as dynamic steering assisted with the physical manoeuvring of the bus, reducing required muscle activity and stress on the body, which in turn should aid neck and shoulder issues and provide a more relaxing work environment overall (Ahlström et al., 2018). Considering ways to reduce mental and cognitive overload for drivers may also be beneficial in terms of counteracting fatigue (Sang & Li, 2012). Design should also be considered in relation to the need for drivers to interact with passengers, and the potential risk and stress due to threats and violence.

3.1.1.4 Fatigue Countermeasures and Prevention Strategies Not Specific to Bus Drivers

3.1.1.4.1 Road Safety Campaigns

Road safety public awareness campaigns have typically been relied upon to prevent fatigue amongst the general public. A comprehensive meta-analysis indicated an accident reduction of 9% in response to these campaigns (Phillips, Ulleberg & Vaa, 2011). Research found that following a national campaign that reached 13% of its audience, professional and non-professional drivers adopted certain fatigue prevention strategies, such as stopping and resting for 15 minutes (Adamos, Nathanail, & Kapetanopoulou, 2013). However, this is a complex issue and transport operations possibly require an approach that incorporates a variety of information such as training and education, organisational strategies, scheduling practices, vehicle and environmental solutions, and research and evaluation (Hart, 2013). There is also the issue of responsibility for fatigue management, as non-professional drivers carry individual responsibility. However, for professional drivers, not only do they carry the individual responsibility, but also responsibility to their industry or company, and the regulatory body that they belong to (Gander et al., 2011). This can be quite confusing, especially if there is a chain of responsibility involved.

3.1.1.4.2 Education and Training Approaches

Educating drivers about the causes and consequences of fatigue in relation to their work, is often advocated as a countermeasure to reduce fatigue. Generally, drivers are educated on various aspects, such as the physiology of fatigue, fatigue management strategies, the safety implications, and any company policies involving fatigue. For example, education to raise awareness of fatigue in heavy vehicle drivers has been adopted in New Zealand (Firestone & Gander, 2010), and in the rail industry in the UK and United States (Office of Rail Regulation, 2012; U.S. Department of Transport, 2012). In some instances, traffic offender programmes involve aspects on fatigue, however these

broad programmes focus more on other issues such as drug and alcohol impaired driving, and are not designed to address fatigue (Faulks, 2012). Despite interest in driver sleepiness increasing over the past two decades, few regulators consider fatigue management a compulsory or mandatory component of becoming a professional driver.

This approach can be useful in terms of educating drivers who are not aware of the risks of fatigue. A study showed that immediate knowledge gained at the time of fatigue management training was largely retained, and many heavy vehicle drivers implemented fatigue strategies both at home and at work (Gander, Marshall, Bolger & Girling, 2005). However, for individuals who drive while fatigued due to other factors, the benefits of educational approaches may be unlikely to make an impact. Research has shown that for non-professional drivers, the main reason for driving sleepy is due to the desire to reach their destination, or because of time constraints (Armstrong, Obst, Banks & Smith, 2010; McCartt et al., 2000; Nordbakke & Sagberg, 2007). Professional drivers have the added pressures of financial and business demands (Firestone & Gander, 2010), highlighting the need to ensure that fatigue countermeasure strategies go further than solely driver education (Jackson et al., 2011). A recent study with long-haul truck drivers investigating the effects of alertness management training on sleepiness found the training had no impact on driver alertness (Pylkkönen et al., 2018) proposing that driver education as a sole measure is not sufficient to alleviate driver sleepiness. However, driver education is an important approach, as research has shown that drivers regularly use countermeasures which have been shown to be ineffective at counteracting sleepiness (such as stopping to take a walk, opening a window, or turning on the radio) (Anund, Kecklund, Vadeby, Hjälmdahl & Åkerstedt, 2008; Schwarz et al., 2012). Driver education would also tackle the issue of the perception of driving whilst sleepy. Typically, in terms of crash risk factors, drivers list sleepy driving after risky behaviours such as speeding, drink driving, and driver distraction (Pennay, 2008; Vanlaar, Simpson, Mayhew & Robertson, 2008), suggesting driving while sleepy is not perceived to be a risky behaviour.

It is important to understand that the purpose of education and training is most often to change an individual's behaviour, which takes time. Therefore, a one-off, training session is unlikely to impact driver behaviour and reduce fatigue and sleepiness. It may be that an approach including a series of sessions, would elicit behaviour change. This could potentially be conducted using an e-learning platform rather than face-to-face. However, again, it would require participant engagement and motivation to change.

3.1.1.4.3 Fatigue Risk Management

Traditionally, transport operator fatigue has been managed by rules and regulations stating upper limits of time spent at work, however criticism has argued that these rules have failed to consider important causes of operator fatigue (Fourie, Holmes, Bourgeois-Bougrine, Hilditch & Jackson, 2010; van Dongen & Mollicone, 2014). Recently, transport companies have been encouraged to implement evidence-based safety management systems with risk assessments and mitigation strategies tailored to company policies, roles, and documents, which should be supported by management commitment to safety, data-driven continuous learning, and a positive safety culture (Lerman et al., 2012). Fatigue risk management systems can vary, ranging from simple or informal approaches, to complex, formal approaches, however the main consideration is the assessment and mitigation of fatigue risks. A recent review focusing on fatigue-related risk, exposure factors and control measures for land and sea transport, identified 13 measures to monitor or control fatigue risks, including: optimal staffing and schedule design, optimisation of breaks and naps, monitoring of actual hours worked, health screening and treatment, monitoring of fatigue symptoms while operating, control of fatigue while operating, and performance monitoring and assistance (Phillips, Kecklund, Anund &

Sallinen, 2017). The review also highlighted the importance of incorporating measures to support any implementation of measures to monitor and control fatigue and associated risk factors, such as organisational learning, training and education, management commitment, recruitment and selection and safety climate and culture.

3.1.1.4.4 Policies Regarding Rest Periods and Hours of Work Restrictions

In an attempt to prevent drivers operating when fatigued, restrictions to work schedules are often utilised by organisations and regulatory bodies, which may include limits to work hours. This approach was established in the 1930s to balance working conditions and pay, limiting commercial drivers to set driving, work, and rest periods (Gander et al., 2011). Restricting hours of work remains a popular mitigation to fatigue risk within transport operations. Non-professional drivers are encouraged to stop and take a break from driving if they begin to feel sleepy or notice symptoms of sleepiness or fatigue, however this may not be as easy or realistic for professional drivers who have schedules to keep. There are certain legal requirements regarding driving hours and rest breaks for long distance truck drivers as well as coach and bus drivers, specifying maximum driving times without breaks, as well as minimum rest requirements between duty periods. Although the impact of work and rest polices on driver fatigue and driver safety has had limited evaluation, research has shown support for the regulation of work hours. It was found that participating in safety behaviours such as driving within statutory hours and observing rest breaks, was negatively correlated with exhaustion, job tension, and fatigue (Boada-Grau, Sánchez-García, Prizmic-Kuzmica, & Vigil-Colet, 2012), and compared to drivers who did not have a rest break, taking breaks during an 11 hour shift reduced the odds of a crash by 68% for one break, 83% for two breaks and by 85% for three rest breaks (Chen & Xie, 2014). However, specific durations of rest breaks and the time the break was taken within the 11-hour drive were not taken into consideration in this study. In comparison, evidence has shown the detrimental effects of working 12 hours or more in one shift. Research involving a large sample of more than 10,000 US workers in various occupations found that working 12 or more hours in a shift was associated with a 37% increased hazard rate (Dembe, Erickson, Delbos, & Banks, 2005). Another important consideration is the ability to cope during extended shifts, and with sleep loss and night work, which has been found to deteriorate with each additional long or overnight shift (Anderson et al., 2012). This research shows that human performance can be negatively impacted by fatigue, and that by setting a limit for hours of work, fatigue related injuries and incidents could be reduced, especially in industries that involve repeated exposure to long, extended shifts (Anderson, Grunstein, & Rajaratnam, 2013).

However, attempting to tackle fatigue solely by introducing specified hours of work and rest can be associated with several issues. Unfortunately, compliance may be a problem, with no guarantee that workers will follow the suggested hours (Balkin, Horrey, Graeber, Czeisler & Dinges, 2011), especially if the recommendations lack additional sanctions. Fatigue detrimentally impacts individuals at different rates, which is not taken into consideration by implementing general driving restrictions and informing drivers to stop after a certain period of time (Williamson, Friswell, Grzebieta & Oliver, 2013). Fatigue can also be due to a number of reasons, both sleep related (including sleep loss, sleep debt and extended wakefulness), or task related (including task duration, and mental under or over load). Therefore, restricting work hours does not account for the cause of fatigue, which may require different and distinct approaches in terms of countermeasures (May & Baldwin, 2009). Fatigue is an important and dangerous issue, and one that needs to be addressed. Encouraging drivers to be aware and notice signs and symptoms of fatigue to enable them to act before safety related incidents occur, may be a more practical fatigue risk management strategy, rather than a standalone overarching approach (Williamson et al., 2013).

3.1.1.4.5 Policies Regarding Other Industry Approaches to Managing Fatigue

In general, there are other management-level guidelines and approaches regarding fatigue, apart from training and rostering polices, that are advocated by workplace health and safety and transport authorities. However, the majority of guidelines can be vague, and it is not always clear how or to what extent they apply in practice. For example, The Health and Safety at Work Act 1974 states that employers have a duty of care for on-the-road work activities and work-related driving activities, and the Management of Health and Safety at Work Regulations 1999 requires health and safety to be managed effectively.

Within the rail industry in the UK, regulation 25 of the Railways and Other Guided Transport Systems (Safety) Regulations [ROGS] (2006) cover fatigue management practices, alongside other guidance. These regulations, as well as the Office of the Rail Regulator who has a Good Practice Guide for management, have resulted in the development of Fatigue Risk Management Systems (FRMS) by London Underground and TfL Rail, comprising of three training courses for frontline staff, managers, and work schedule compliers. However, as the requirements of ROG25 apply to public transport under the sphere of ROG, they do not apply to all forms of road transport which includes buses. The Rail Safety and Standards Board [RSSB] have also developed several fatigue management guides (RSSB, 2012) and good practice guides for managing occupational road risk associated with driver fatigue. The UK aviation industry requires airlines to provide initial and recurrent fatigue management training to crew members, personnel responsible for the preparation and maintenance of crew rosters, and management of said personnel. However, the training programme can be established by the individual airlines rather than an overarching, standardised fatigue management programme, although a training syllabus is suggested within the European Aviation Safety Agency (EASA) Flight Time Limitation (FTL) regulations, including causes and effects of fatigue, and fatigue countermeasures (Civil Aviation Authority [CAA], 2017).

There are different approaches to fatigue management within industries, however it is clear that both individual employees and employers or operators all contribute to the management of fatigue.

3.1.1.4.6 Other Available In-vehicle Technologies

There are limitations associated with organisational and regulatory approaches to driver fatigue (Balkin et al., 2011), as well as the notion that drivers often downplay the consequences of fatigue, ignoring the early warning signs (Fletcher, McCulloch, Baulk, & Dawson, 2005), or failing to take appropriate action prior to a collision (Alioua, Amine, & Rziza, 2014). Due to this, in-vehicle technologies have emerged as a solution to mitigate the effects of fatigue. It has been proposed that the ideal fatigue monitoring system should firstly ‘predict’ fatigue before safety and productivity is impacted, secondly, ‘measure and monitor’ the effects of fatigue, and lastly, provide an appropriate ‘intervention’ when any deficits are detected or anticpated. Current technological designs to counter fatigue involve driver monitoring technologies, fitness-for-duty technologies, and performance-based monitoring (Balkin et al., 2011).

To detect changes in both driver state and driving performance, a variety of invasive and non-invasive technologies have been proposed (Merat, Jamson, Lai & Carsten, 2012). Current commercially available in-built countermeasure systems are designed to provide feedback via messages and alerts, an example is the ‘coffee cup’ symbol which appears on the instrument panel, usually accompanied by an auditory alert. Other systems provide binary alerts (such as warning/no warning), or continuous feedback in the form of an ‘attentiveness scale’. Vibration feedback has also been developed, delivering alerts via the seat or steering wheel, for example haptic guidance steering systems (Wang, Zhang, Wang, Schnelle & Wang, 2017), usually accompanied by an icon warning. In the majority of cases, these messages must be acknowledged by the driver to clear

them. However, there is limited evidence into the effectiveness of these feedback countermeasures for drowsy driving. Research has shown that simple auditory and visual warnings resulted in improved lane keeping (Berka et al., 2005; Fairclough & van Winsum, 2000), and combined auditory and visual warnings were found to improve driving performance and reduce subjective drowsiness over 4-hour drives (Grace & Steward, 2001). However, these simple in-vehicle countermeasures can reduce the frequency of drowsy lane departures in relatively short drives (Gaspar et al., 2017). Objective physiological and physical measures include electroencephalography (EEG) which measure brain wave activity, eye tracking devices that can detect a range of blink or eye gaze patterns, head pose estimations for head nodding, measures to track heart rate and heart rate variability, actigraphy technology which measures gross movement, and devices to detect yawning (Alioua et al., 2014; Balkin et al., 2011).

Fitness-for-duty approaches often involve vigilance or alertness testing, for example using the psychomotor vigilance test (Baulk, Biggs, Reid, van de Heuvel & Dawson, 2008), performed before a work duty, to assess the drivers' alertness and ability to safely commence a driving shift (Balkin et al., 2011; Ji, Lan & Looney, 2006), or eyelid-based measures (Ahlström et al., 2013). However, results have not been shown to reliably equate to poor driving performance (Dawson, Searle & Paterson, 2014), and approaches such as these can be sensitive to countermeasures such as caffeine or pharmaceuticals, possibly exaggerating alertness and capacity to drive at that time (Balkin et al., 2011). They are also considered impractical for commercial driving (Dawson et al., 2014), and therefore not sufficient as a stand-alone method for predicting a driver's ability to remain alert and safe for the duration of their duty period (Balkin et al., 2011).

Several fatigue monitoring technologies for use in the transport industry are commercially available in the US, UK, and Europe (Dong, Hu, Uchimura & Murayama, 2011). Although not exclusively for fatigue mitigation, camera based Lane Departure Warning Systems (LDWS), which employ various algorithms to estimate the state of the vehicle (speed) and road positioning or alignment (lane width), have been designed to prevent 'run-off-the-road' crashes (Houser, Murray, Shackelford, Kreeb, & Dunn, 2009), and have been distributed within the US trucking industry. Other on-board safety systems have been considered for use within various transport operations, including military vehicle and truck drivers (Dinges, Maislin, Brewster, Krueger, & Carroll, 2005), with the aim of reducing fatigued driving (Dinges et al., 2005; Houser et al., 2009; Kerick, Metcalfe, Feng, Ries, & McDowell, 2013). A review of other avaialble technologies was conducted by Kerick et al., (2013). These technologies include vehichle enviroment monitors (e.g. SafeTrak) which alerts drivers to erratic driving and lane departures, senor-based monitors (e.g. Advisory System for Tired Drivers, ASTiD) which can track steering behaviour, and smartphone apps which can record and evalute sleep history (e.g. Fatigue Calculator). Driver performance feedback technologies could be effective in terms of self-enforcement, by delivering feedback to both the driver and their employer. This approach has been developed and used with the aim of tackling risky driving in young, novice drivers, installing monitoring devices to deliver feedback to drivers and parents (Guttman & Gesser-Edelsburg, 2011).

3.1.1.4.7 Self-administered Countermeasures

Sleepiness countermeasures can be utilised to reduce the likelihood of having a sleep-related crash (Cummings, Koepsell, Moffat & Rivara, 2001), however, there are a range of measures used by drivers, with varying degrees of effectiveness. 'Strategic' measures include not driving during the night and ensuring that adequate sleep has been obtained before driving, however this can be unrealistic in terms of professional driving. Popular measures such as opening the window, turning on the radio, and taking a break, have been shown to be ineffective at improving alertness for

extended periods of time (Horne & Reyner, 1996; Reyner & Horne, 1998; Schwarz et al., 2012), despite these two in-vehicle countermeasures (opening the window/turning on the air conditioner, and listening to music) being utilised more so than effective roadside countermeasures (Anund et al., 2008; Armstrong et al., 2010; Nordbakke & Sagberg, 2007). This therefore highlights the importance of education surrounding the use of effective and ineffective countermeasures to sleepiness.

One of the most effective ways to counteract sleepiness is by taking a 15-20 minute nap, which leads to reductions in physiological and subjective sleepiness, and improves driving performance (Horne & Reyner, 1996, Leger, Philip, Jarriault, Metlaine & Choudat, 2009; Watling, Smith & Horswill, 2014). However, again, for professional drivers this may not be possible due to time constraints and inadequate facilities. An important sleepiness countermeasure is caffeine. Caffeine is found in a variety of products, such as coffee, tea, chewing gum, and energy drinks, and is widely used in Western society to increase alertness (James, 1997). Consuming caffeine has been seen to effectively increase alertness and improve driving performance after 20 minutes (De Valck & Cluydts, 2001; Horne & Reyner, 1996; Reyner & Horne, 2002), with a caffeinated nap (consuming a caffeine drink followed by a short nap), significantly reducing driver impairments, subjective sleepiness, and EEG signs of sleepiness (Horne & Reyner, 1996). The beneficial effects of this countermeasure have also been shown in laboratory studies with other performance measures (Tietzel & Lack, 2002; Wesensten, Killgore & Balkin, 2005), however few countermeasures have been evaluated on real roads.

3.1.1.4.8 Environmental Strategies and Infrastructure

Another common approach to managing fatigue, is the use of environmental or road-based strategies. These include “rumble strips” or audible edge lining, which alerts the driver when they depart the road or highway (Noyce & Elango, 2004), and rest areas that allow drivers to be able to take adequate breaks during shifts (Baulk & Fletcher, 2012). Rumble strips on the centre line have been associated with a 15% accident reduction (Mahoney, Porter & Donnell, 2003; Persaud, Retting & Lyon, 2003), with a 20% reduction in the number of fatalities and seriously injured parties in all crash types, and a 27% reduction in single vehicle crashes (Vadeby & Anund, 2017). A 40-50% reduction for rumble strips on the shoulder (Gårder & Davies, 2006) has also been found, as well the implementation of rumble strips being useful for distracted drivers. However, in terms of sleepiness, the alerting effect of hitting the rumble strip is often short lived, with signs of sleepiness returning after approximately five minutes (Anund et al., 2008).

Crash reduction has been shown in those individuals who utilise rest stops or service stations (Cummings et al., 2001). A later study showed limited effects of motorway service areas, or signs encouraging drivers to take a break prior to service areas for general crashes, however crashes related to sleep did show a reduction (Reyner, Flatley & Brown, 2006; Reyner, Horne & Flatley, 2010). Research has also shown that drowsiness during driving may be prevented to some extent by cognitive alertness maintaining tasks (except sleep deprivation induced sleepiness) (Gershon, Ronen, Oron-Gilad & Shinar, 2009; Oron-Gilad, Ronen & Shinar, 2008; Song et al., 2017).

In terms of road construction and design, laboratory studies have shown that sleepiness increases faster during monotonous driving (Richter, Marsalek, Glatz & Gundel, 2005). However, the majority of driver sleepiness studies are conducted in either driving simulators or in laboratories with monotonous driving conditions. A study investigating indicators of sleepy driving in more challenging conditions found differences in indicators following sleep loss depending on whether the driving was moderately or very challenging, highlighting the importance of the driving situation (Anund, Kecklund, Kircher, Tapani & Åkerstedt, 2009).

3.1.1.5 Gaps and Future Challenges

The review has identified several gaps and future challenges relating to the literature and current approaches to managing driver fatigue.

To summarise, these include:

- There are varying definitions of fatigue, with terms such as “fatigue” and “sleepiness” being used interchangeably both within the literature and within occupational settings;
- In general, the exact number of incidences of fatigued driving is not known due to reporting issues and the fact that the majority of the time, only those involved in crashes are recorded;
- The range of existing countermeasures to fatigue with limited information and evaluation relating to their effectiveness;
- The inconsistencies within different industries at which fatigue management is enforced and training is delivered.

More specific to bus drivers:

- Overall there is a dearth of bus driver focused research in relation to fatigue and fatigue management;
- There is a lack of subjective research exploring bus driver opinion relating to their role as a bus driver, their background and health, their sleep patterns, and also specifically in relation to how fatigue influences or is influenced by bus driving, and how this is managed;
- Objectively measured research is also limited, aimed at investigating bus driver fatigue in real-life, on-road settings.

3.1.2 Summary

Overall, the review has highlighted that:

- Fatigue is considered to be a generic term including both sleepiness due to the circadian low or lack of sleep, and task related fatigue due to both work underload and overload.
- Fatigue in bus drivers is an under-researched area, with only 26 papers in total being identified within the past 12 years. Sleepiness risk in relation to driving is often underestimated.
- Driver sleepiness is an important topic and has been shown to be an issue in other driving groups, and within other industries, contributing to approximately 15%-30% of road traffic crashes. The risk of being involved in a road traffic accident more than double when driving whilst sleepy, and driving performance following 17 hours of wakefulness is the equivalent of a BAC of 0.05.
- Aspects of professional driving are risk factors for fatigue, such as sedentary/restricted posture, long driving hours, irregular shift patterns, extended shift duration, reduced sleep, early morning shifts, night shifts, low task demand.
- Fatigue is a problem globally for bus drivers, resulting from a combination of factors such as scheduling, shift patterns and irregularity, time of day of operating, and working conditions, with many of these directly effecting sleep quality and quantity.
- Many effective countermeasures such as napping, caffeine, and reduced night time driving may not be practical or suitable for bus drivers. Many countermeasures also rely on driver motivation and engagement.

- There is minimal research relating to the evaluation of reported countermeasures in relation to reducing driver fatigue. Therefore, it is difficult to draw conclusions on the effectiveness of certain mitigation strategies.
- Implementing countermeasures to address single aspects may be limited in their potential to reduce driver fatigue compared to a more inclusive, holistic approach.

3.2 Task 2: Internal policy review

3.2.1 Key findings

The two approaches employed to review fatigue policies within the 10 London bus operators were a questionnaire providing general details about each operator and a request for details of the operator's policy on fatigue management with examples of the relevant documents. For the first element, central managers (one from each operator with names being provided by TfL) completed a questionnaire about issues related to fatigue management and to provide some context for their organisation's operations. A variety of personnel responded, for example, Head of Operations, Driving Standards Manager and Transport Safety Manager. This questionnaire can be found in Appendix H. Each operator completed the questionnaire independently, consequently the level detail provided to open ended questions varied.

The questionnaire showed that the number of London bus drivers employed by each operator ranged from 15 to 6,232. The average length of time for which bus drivers have been employed at the operators ranged from 2 years to 10-15 years. The proportion of female drivers ranged from 2% to 15%, with the majority being around 10%. The number of buses in operators' fleets ranged from five to 2500 (with half having more than 1000) and the make/models were numerous; the number of garages in London ranged between one and 17. In eight of the responding operators drivers have a fixed base depot; in the other two, workers operate out of two garages.

With regard to fatigue management policies, no operator provided an existing fatigue management policy, although two operators noted that they were about to address the issue in a more targeted way. In lieu of a formal fatigue management policy, operators were asked to provide any existing documents which contain information which may be relevant to fatigue management e.g. driver hand book, training manuals etc. Nine of the 10 London bus operating companies sent whole relevant documents with a further one answering specific questions and/or sending pages or sections as appropriate. The exact documents provided varied between operators.

Table 3.2 lists the types of policy documents provided. It should be noted that any documents discussed here are those which operators elected to send and which they therefore considered to be pertinent to policy surrounding fatigue/tiredness. As a result, it is possible that operators hold additional policy documents which, for various reasons, they did not share with the researchers. Consequently, the Table shows only where a document was provided; blank cells do not necessarily denote that an operator does not have such a policy document, simply that they did not share it. The range of documents and lack of clarity surrounding the policies provided by the operators both demonstrate the differing stages of comprehension and consideration of fatigue currently being experienced in the bus driving industry in London. Within the policy documents provided there was a range of information which related to fatigue management. The key features of which are noted in Table 3.3.

Table 3.2: List of policy documents provided

Type of policy document	Operator no.									
	1	2	3	4	5	6	7	8	9	10
Documentation detailing fitness to work confirmation procedures	✓									
Driver work hours rules	✓			✓	✓	✓		✓	✓	
Driver handbook	✓			✓	✓				✓	✓
Medical assessment procedures/questionnaires	✓				✓				✓	
Accident procedures and processing included in incident reporting	✓								✓	
Driver training/coaching materials	✓		✓	✓		✓			✓	
Disciplinary and Performance Improvement Policy and Procedure		✓							✓	

Table key: ✓= document provided by operator

Table 3.3: Fatigue management relevant content of policy documents

Fatigue management relevant content in policy documents	Operator no.									
	1	2	3	4	5	6	7	8	9	10
HSE Fatigue and Risk Index Calculator output considered	✓						✓			
Fatigue management content in Driver training			✓	✓					✓	
Fatigue management content in Driver handbook									✓	✓
Regular communications are sent to drivers related to health and wellbeing (leaflets, posters, noticeboards and information screens – may not be fatigue specific)	✓				✓			✓	✓	
Additional parameters applied beyond mandated hours of driving regulations aiming to ensure drivers do not become fatigued	✓								✓	
Medical examinations document mentions fatigue	✓								✓	
Medical self-certification Health Assessment questionnaire – asks about sleeping disorders and medical condition affecting sleep	✓								✓	
Explicit mention of provision of rest rooms at depots and bus stations	✓								✓	
Disciplinary and Performance Improvement Policy and Procedure explicitly mentions fatigue		✓							✓	
Risk assessments and medicals performed regularly on drivers who have medical issues					✓					
Mentor's Guide mentions fatigue as an indication of emotional difficulties						✓				

Table key: ✓= feature mentioned in at least one document provided by operator

It is noteworthy that the policy documents which were provided did not always correspond with the responses to the questionnaires. In particular, all 10 questionnaire respondents noted their legal obligations in relation to driving time limits and communicated this to their drivers either in the driver's handbook, at induction, or in a rule book (sometimes in multiple ways). Only six sent relevant documents, although several stated this to be important in their fatigue management, and some had introduced additional parameters to the regulations to avoid fatigue in their drivers.

Four operators who provided driver training or handbook documents included a specific mention of fatigue (operators 3, 4, 9 and 10). Additional operators provided similar documents but fatigue was not mentioned, specifically two operators provided documents which did not include a consideration of fatigue for each of: driver training materials (operators 1 and 9); new driver induction (operators 1 and 6); driver handbook (operators 1, 4 and 5) and directions to drivers on how to report accidents/incidents and near misses (operators 1 and 9).

Seven operators indicated that drivers were required to confirm their fitness to drive. This was noted either according to the questionnaire responses, where three operators stated drivers confirm their fitness to drive by signing in, and a further two reported having an automated sign-in system making this explicit. Two additional respondents explicitly stated that drivers are responsible for ensuring they are fit for work (rather than stating that they are required to sign in to confirm this). One respondent noted drivers are obliged to tell the employer if they think they are unfit to drive, and another noted their attendance policy states drivers should not work if unfit to do so. In the final operator who provided documents, duty managers make visual checks at sign on when they interact with drivers.

Seven operators noted that procedure on feeling unwell while driving the bus is part of their attendance policy and drivers should stop the bus in a safe place and radio through that they are unwell. Medical assistance may be called, and if it is a case of the driver needing to go home they will be picked up. This issue is generally communicated to drivers at induction or during the training process. Two operators stated that all policies concerning health and feeling unwell are covered in their handbook, whilst another reported no formal policy.

All 10 respondents include a consideration of driver fatigue in their crash/incident investigation system; this takes a variety of forms. For example, via a reporting system capturing various forms of data following an incident (when a driver last worked, how much rest they have had the previous night, how many days since their last full rest day, which shift it occurred on, if the work was overtime or normal work), through the use of a post-accident interview, and by reviewing camera footage where available.

With regard to pre-employment medical fitness tests, seven of the responding operators noted adhering to the DVLA legal requirements according to age. In addition, one operator noted that any of their drivers working night shifts complete a medical questionnaire every two years, with any concerns resulting in a visit to the occupational health doctor. A second operator noted additionally that health checks are introduced if a driver is involved in multiple incidents and another has an occupational health doctor for drivers who have been on long-term sick leave. Only one operator stated that their drivers are not subject to medical fitness tests.

In six operators, drivers are paid by the hour on a weekly basis. Four operators have a weekly wage; in two of these drivers are paid on a salaried basis. One operator has six 'casual' drivers who must work at least one shift every 12 weeks, whilst another has 22 part-time workers who work 2, 3 or 4 days per week. All of the eight respondents running night buses offer financial incentives to work nights, including an enhanced rate of pay, unsocial hours payments and night bonuses.

Most of the operators run a mixture of shifts, including: mixed rota of rolling 'earlies', 'middles' and 'lates' and fixed either early or late shifts. This may include 'family friendly' work, for example 'earlies' may be requested to allow those with young children to be available to collect them from school. Night bus drivers generally work only fixed night-time rotas. All of the operators allow drivers to swap shifts, usually this is achieved by mutual consent between individuals. Requests generally must be made in writing and it is the responsibility of drivers to check adherence to the drivers' hours and regulations when swapping shifts.

Five of the respondents operate 24 hours per day, seven days per week. Of the remainder, one noted that most routes are 20-24 hours, a second stated that it is 24 hours where night services operate. A further respondent noted that some routes are 18 hours, and some are 24 hours, one runs 22 hours per day (04:00-02:00) and the remaining participant has a TfL contract running 04:30-21:00 hours.

Night shifts were defined in a variety of ways:

- Signing on between 19:00 and 02:00, and signing off after 03:00
- Starting anywhere between approximately 20:30 and 01:00
- Duties that start and finish between 18:30 and 10:00, although the majority are between 19:00 and 07:30
- Working between 02:00 & 03:00
- Approximately 23:00 to 06:00
- 22:00 – 04:00 generally
- Not defined but generally finishing after 03:00
- Any duty that works the full hour between 02:00 and 03:00

For five respondents, schedules are planned via their Schedules Department, with two specifying this being done in accordance with the service specification for any given route as set out by TfL and within company agreements. A further respondent mentioned schedules being planned by computer followed by a manual check and update.

At the time of writing there are no imposed TfL requirements or policies on fatigue management for buses, and it is left to the operators to follow legal and union requirements. However, fatigue does feature in the Safety Assurance Process, an ongoing assessment process which has recently replaced annual audits. The assurance score is generated during regular safety conversations with the operators, where TfL Safety Managers talk to staff at all levels, including drivers.

The fatigue questions included in the Safety Assurance Process are as follows:

- Are there fatigue prevention measures included within risk controls in risk assessments?
- Are drivers educated on fitness to drive standards? That is, is there an education programme that informs drivers of the minimum standards that apply in this regard?
- Is driver fitness to drive considered post incident?
- Do drivers know how to declare themselves unfit to drive?
- Is fatigue management considered to be a key risk control?

A relevant public transport comparison is the fatigue management policy related to rail (over ground, tube and tram). In the case of London Underground (operated in-house) and TfL rail (which is contracted to MTR Corporation), regulation 25 of the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) and other guidance together cover fatigue management practices are applicable. These Regulations apply to the mainline railway, metros (including London Underground), tramways, light rail and heritage railways. Furthermore, the Office of the Rail

Regulator has a Good Practice Guide for fatigue management from which further Fatigue Risk Management Systems (FRMS) were developed. Since this is driven by ROG regulator, the same policy applies to both tube and overground rail. The FRMS is integrated into TfL's safety management system. Within the FRMS there are requirements for managing the risk of fatigue and also three training courses: one for frontline staff (manage your own fatigue roles and responsibility), one for managers (policy requirements) and one for work schedule compilers (roster design). It is provided to the tram companies, although in contrast to underground drivers, tram drivers are not employed by TfL. Tram fleet and infrastructure maintenance staff all work for TfL, so are subject to the FRMS.

The requirements of ROG25 only apply to public transport domains which come under the ROG remit and therefore are not applied to road transport including buses. Consequently, formal fatigue management is in place to cover drivers of rail related public transport in London. TfL has identified that it does not have a standardised approach across all transport public modes; this has led to a maturity review which has concluded that there is a need to place fatigue management requirements onto TfL suppliers, including buses.

3.2.2 Summary

Within London bus driving, no operator has an explicit policy for fatigue management. This might be expected as TfL does not mandate fatigue management policy. This is in contrast to rail public transport which is subject to dedicated fatigue management requirements imposed by ROG 25. From the policy documentation provided by the operators for review there are indications that:

- None of the ten operators has a formal or specific policy on fatigue.
- Eight of the ten operators stated a recognition of fatigue as an issue to be addressed, with two of these noting they were about to address the issue in a more targeted way.
- Only two operators provided information about using the Health and Safety Executive (HSE) Fatigue and Risk Index, a freely available tool to help prevent driver fatigue.
- All ten operators are aware of the Drivers' Hours and Regulations which mandate maximum working hours.
- Two of the operators indicated that they have put in place additional parameters to these Regulations to help ensure drivers do not become fatigued.
- Most London night bus drivers only work on night-time shifts, although the definition of a night-time rota differs across the operators.
- Most of the operators run a mixture of shifts (earlies, middles, lates), with only two not running at night.
- Drivers can apply for a certain shift at some operators; this includes 'family friendly' work, particularly 'earlies'.
- Shifts are allocated according to route knowledge and experience.

3.3 Task 3: Focus groups with bus drivers

All ten of the London bus operating companies participated in bus driver discussions in some way. That is, eight focus groups with 6-8 participants were held whereas at one operator, two groups of four were organised due to the lack of availability of drivers. The last operator was also unable to provide 6-8 drivers at one time and so arranged three interviews with single drivers.

At the beginning of each focus group, participants were asked to complete a short questionnaire relating to demographic information. The total number of participants in the bus driver focus groups was 65 (including the three interviewees) and 80% were male, with 20% being female. As shown in Figure 3.1 (below) the majority of participants were aged 45-54 years (35.4%), with 26.2% being in

the age range 54-65 years, 21.5% in the age range 35-44 years and the remainder 25-34 years (16.9%).

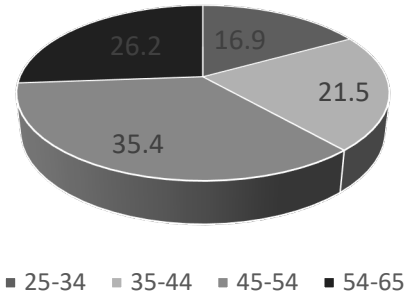


Figure 3.1: Age of focus group participants (%)

The participating bus drivers had been working on average 13 years and 6 months as a bus driver and 8 years 1 month on average as a driver for their current employer. Thirteen participants (21% of those responding) had been working in the bus industry for more than 25 years, demonstrating the long service of these drivers. Drivers worked a variety of different shift schedules, with the majority of drivers working early, middle or late shifts; these were self-selected without specific times due to variation between the operators (see Table 3.4).

Table 3.4: Types of shift driven

Type of shift	Number*
Early	58
Middle	39
Late	32
Night	7
Total	**136**

* Respondents were able to select more than one option

When asked to provide their number of hours worked per week, many found this problematic due to the variable nature of their work, with shifts and overtime liable to change from week to week. The whole numbers provided ranged from 9 hours to 60 hours per week. Where a range of hours was quoted, these varied from '35-40' to '60-72' (37 drivers in total). Of the remainder, four stated '38+' hours, three stated '40+' and one stated '45+'. Four participants did not respond.

3.3.1 Key findings

The focus groups proved to be wide-reaching and informative, with many elements of agreement between the participants. Perhaps most importantly, all of the participants acknowledged that they believe that fatigue is an issue amongst London bus drivers. A small number of participating drivers do not generally feel fatigued, but they recognise it amongst their colleagues. In total 14 themes were identified.

3.3.1.1 Commuting

The focus groups showed that drivers might live a long distance from the sign on point of their bus routes, which is usually a garage or depot. Commuting times of up to one and a half to two hours

each way were quoted by participants (in four focus groups); this was their own commute, or sometimes that of colleagues. This was sometimes due to drivers having moved away from London or might also be a result of the TfL tendering process. This means that, following the tenders going out, certain routes may pass between operating companies and no longer be based near to the drivers' base garage. This can add to commuting times for certain drivers. These long periods of time spent travelling to work are clearly a cause of fatigue, as they informally add to the hours a driver spends on the road. It is clear, however, that commuting by public transport does permit drivers to sleep before beginning a shift; several said that they take advantage of this possibility if they can.

Many routes operate away from the driver sign-on point, so after signing on drivers are required drivers to travel before they begin driving. This is included in the work time and is paid, however, it can be a cause of additional pressure and fatigue to drivers due to trains and/or buses running late.

3.3.1.2 Countermeasures

A variety of actions are undertaken by drivers if they are feeling fatigued whilst driving a bus. These include the commonly undertaken actions of opening the window or getting out of the bus to get some fresh air, taking caffeine supplements and/or drinking (water, hot drink, energy drink), although there was some debate around whether drivers are permitted to drink whilst on duty. Stopping the bus and getting out might not be popular with passengers or controllers, so some drivers noted having invented a possible problem on the bus (back window, tyre, etc) in order to get out at a bus stop and walk around the vehicle and investigate.

The drivers recognised that having a healthy diet and undertaking exercise can both help in countering fatigue, although several noted the difficulties they face through working on shifts. That is, beginning a shift in the early morning or late evening can disrupt eating patterns, meaning that regular meals cannot be taken at the usual time. In addition, it can be difficult for drivers to find time to exercise, given the unsocial hours which they work, the sometimes short periods between shifts, and their family commitments.

Several of the focus groups suggested that having music on the bus would help to keep drivers alert, and noted that they might have had portable radios quietly playing in the cab prior to this being prohibited. Others noted singing and talking to themselves and interacting positively with passengers as a means of avoiding fatigue.

When the bus is stationary during a stand time, one driver reported reading a book and several others noted having a quick sleep (or power nap) to refresh themselves. This has more than once led to a driver oversleeping or needing to be awoken by a colleague or passenger. Another way of resting is to relax, with one driver commenting: "we don't wait until we feel tired before we rest. Any moment we have we just relax, so that the muscles become relaxed as well. Once the muscles are relaxed, they affect the brain, the brain also relaxes. So any time I'm off, I just sit down somewhere and relax … during my breaks, stand times, whatever, I just relax myself."

3.3.1.3 Definitions and understanding of fatigue

In order to reinforce the project definition of 'fatigue', participants were asked to discuss their understanding of the term at the beginning of each focus group. In many cases, their first response was 'tired' or 'tiredness', with one driver stating the following: "over-tired, being over-worked and not having enough sleep, all that sort of thing". Lack of sleep, exhaustion, drowsiness and insufficient rest time were also cited here, with drivers being well aware that good quality sleep is the key to avoiding fatigue. Sleep deprivation was a particular concern, with suggestions that drivers

find it difficult to sleep at unconventional times (e.g. 7.00pm) or may be out late socialising and so will be having a limited amount of effective sleep in advance of shifts beginning.

The drivers also recognised a difference between being mentally and physically tired, although they perceive these to be inextricably linked: “physical and mental, all involved. It’s a concentration of all of the body”. It was also suggested by participants that mental fatigue takes a toll on physical. They noted having to be constantly mentally alert, otherwise the potential for an accident will increase. They suggested that mental fatigue and overload are closely linked to stress and agitation. Participants described fatigue as an impairment of ability and alertness due to the events of day such as grief from passengers, traffic and radio/ controllers. Other drivers mentioned boredom, irritability, being short tempered, losing concentration and slower reaction times.

With regard to physical concerns, participants noted that the body can feel tired through the structure of the cab, the sitting position and an inability to stretch over a long period, making them physically fatigued. Some drivers suggested that mental fatigue is more significant, with physical fatigue being simpler to overcome with certain countermeasures.

Shift work was cited as causing fatigue, with mixed shifts affecting the body’s systems due to severe changes in start and end times, or to beginning and finishing work in the dark. The repetitive nature of some shift patterns was also discussed in the context of fatigue.

3.3.1.4 Facilities

A lack of suitable facilities was often cited by drivers as a cause of fatigue. For example, some operators have organised break times at bus stops rather than stands or garages. This can often mean that drivers are compelled to rest and eat on the road, rather than in a warm and sheltered place where they can sit and relax. If they go to a café or restaurant, they will have to pay and may not be able to find healthy food. Where there is no canteen at a changing point it is often necessary for drivers to commute to a place to find food, and eat a heavy meal causing feelings of drowsiness when returning to drive again.

Canteen facilities are provided at many garages and depots but are likely to have limited opening times and will not necessarily be open during early or late shifts. Furthermore, participants claimed that the canteens they do have are unlikely to offer healthy food. In other places, microwave ovens are available, but often shared amongst a large number of people making it difficult to gain access during a standard break.

A general lack of rooms in which to rest at the garages and depots was also cited as a barrier to being able to relax and perhaps sleep before shifts and during breaks (including those which are part of a spread-over shift). Participants clearly believe this to impact on fatigue levels.

Taking breaks on the road draws attention to another problem whereby drivers do not have access to toilet facilities. This causes worry to drivers who may consequently not drink sufficient liquid for fear of needing to urinate whilst not having access to these facilities. In addition, two of the female participants noted not having easy access to a bathroom during their menstruation period. However, it should be noted that TfL are currently running a project which will provide a minimum of 41 new toilet facilities for drivers on routes which do not currently have toilet facilities available.

Drivers are aware of the positive effects of exercise, both for general health and in helping to avoid fatigue. To this end, they would like their employers to provide exercise equipment at work or discounted access to a local gym. They also noted that shower facilities would aid in them cycling or

running to work as a means of exercising. It should be noted that some operating companies already provide such facilities, which was positively described by the relevant participants.

3.3.1.5 Money

Budgetary concerns are an important matter for the drivers. They suggested that pay rates are insufficient due to monetary pressure on the operating companies and many drivers take on overtime to make up for the shortfall. As noted by both bus drivers and their managers, there is currently a shortage of drivers which provides ample opportunity for overtime. This then has an effect on their rest times and can mean shorter periods between shifts, getting close to the legal regulations. It can lead to drivers suggesting that they drive only for the money, rather than for passion about driving and the interaction with passengers inherent in working on a bus. In addition, participants at several operating companies believe that drivers are earning differing pay rates, which may be due to variations in driving experience, or to operators taking over other companies and inheriting drivers on alternative pay scales. These differences in pay may cause feelings of unfairness and irritation. It should be noted that a recent TfL initiative (Licence for London) aims to enable bus drivers to move employer whilst receiving a similar rate of pay to colleagues with comparable lengths of service.

3.3.1.6 Other road users

A key source of mental fatigue for the participants is other road users and the road furniture which they encounter. Of particular note is the volume of traffic on certain routes, which causes the drivers to deviate from the schedule, leading to complaints from passengers and interventions from the controllers. It also means drivers are required to employ a greater level of concentration and attention to the road. It was also noted that traffic will increasingly be a problem as a greater number of vehicles appear on the road, there is an increase in shared cycle pavements, trucks and vans delivering, and people walking in the road, stepping out too close to the edge.

Cyclists were also cited as a cause of mental fatigue for drivers, particularly where they do not use the dedicated cycle lanes but ride “slowly” along the bus lane. One driver stated that cyclists riding in front of them were adding to their stress by forcing them to drive more slowly. This was a particular annoyance to them as they considered that similar behaviour on the part of the driver would see them reprimanded and/or fired. One participant reported that the erratic riding of a cyclist has caused a them to brake hard, causing one of their passengers to fall over and leading to the driver feeling stressed. It was reported that cyclists may also feel intimidated by buses, becoming scared and attacking drivers through their window or breaking their mirror and riding away. The drivers reported this as a cause of mental fatigue, indeed one focus group was clear that cyclists were perceived to be the biggest cause of fatigue for them. However, another driver noted seeing “good cyclists and … bad cyclists”.

Drivers also brought up issues about the road furniture and parking practices, noting the large size and slow brakes of the bus. They suggested stress and fatigue can be caused when attempting to manoeuvre around the London roads.

3.3.1.7 Reporting fatigue

The study is investigating how fatigue and sleepiness are managed at work, and to this end drivers were asked about their experiences of reporting fatigue. The majority of participants know how to report fatigue, but many are unsure of how this would be handled by managers, and few have ever reported feeling fatigued. A small number of drivers were comfortable with reporting fatigue, and had experience of doing so, citing their worries about the safety implications of carrying on working while tired. Others believed that they would face discipline if they admitted to feeling tired and

suggested they would be more likely to call in sick in such a situation. In these cases there was generally a reluctance to being assessed by the operator, and potentially being offered medical support. Participants suggested that they were 'not allowed' to be tired and were unlikely to discuss fatigue either with managers, supervisors, or other drivers. This demonstrates a perceived lack of support from the operator around fatigue, suggesting a closed culture around the subject, with drivers suggesting managers do not understand their working roles.

Some participants had received advice on combating fatigue and others reported having a company handbook containing such information; this was considered to be insufficient and was often in the form of posters which are thought to be ineffective. They also suggested that this information is often not new to them, but instead provides solutions which are unrealistic for them on an everyday basis. For example, the advice may cover healthy eating, but shift work and a lack of a canteen or choice of eating place make it difficult to have such a diet.

There was a general awareness of new computer fatigue monitoring technology which is being piloted at the current time. Drivers were generally apprehensive about these, but none had sufficient experience of them to give a robust opinion.

3.3.1.8 Shift patterns

The focus groups showed that shift patterns are a significant issue for bus drivers in the context of fatigue. Where they saw problems within their shifts, the drivers had a variety of suggestions for what they considered to be more effective working patterns. There was also a general wish for shorter hours with better pay, which it was thought would lead to a reduction in fatigue.

As a result of the wide variety of shifts being offered by the companies and being undertaken by the drivers, it is difficult to consider all of these within these findings. However, there follows a consideration of the key issues which were discussed.

Participants commented on the difficulties of their shifts changing from week to week. For example, on a regular rota one week might be early shifts, the next middles and the next late shifts. Some of the drivers noted that their body clock becomes used to a certain sleep pattern for one week and then quickly has to change sleep pattern – they find it hard to adjust. This then affects eating (maybe having lunch or breakfast at 10:00). The next week the shift might begin at 16:00 and lunch will be at 19:00 or 20:00, necessitating a change in body clock every week. In addition, having a week with very early morning shifts will cause cumulative sleep deprivation and fatigue. This is in line with the results of the on-road study in terms of sleep duration.

Some drivers are permitted to work on one shift pattern, for example, an early shift which allows workers to finish in time to collect their children from school. Participants on these types of shifts tended to be those with young children, or those with long service who participants saw as having 'earned' the right to such a dispensation. Some drivers drive night shifts only, although these were thought to be particularly fatiguing by the focus group participants who sometimes drive the bus at night. It should be noted that there were few night drivers participating in the focus groups because these all took place during the day when night drivers are inevitably not on duty. Other drivers noted that only a small number of drivers are usually permitted to work on one shift and that it is therefore difficult to become one of those.

There were participants working as 'spare' or standby drivers; these cover shifts when the usual drivers are on leave or sick. Some noted enjoying this way of working, suggesting that it avoids the monotony of driving the same route all the time. However, due to the nature of the role, notice of the hours to be worked may be only 24 hours (the minimum period) in advance. This, and the

difficulty of changing shift every day, can make other aspects of the driver's life difficult to plan, particularly in terms of healthy amounts of sleep. Sudden shift changes are stated as a source of fatigue and stress for all the drivers, not just spares (who anyway represent a very small percentage of the driving population in any garage).

The drivers were all knowledgeable about the legal limits of driving, and most companies had a driver portal or other computer software to inform drivers of their shifts and allow them to check their hours are compliant. This was very important when swapping shifts; the arrangements were routinely left to drivers to decide between themselves but then checked by a scheduler or manager before being made official. All operating companies allow drivers to swap shifts within the legal limits. The portals and scheduling also mean that drivers can potentially be aware of their future working hours up to a year in advance.

Overtime is an integral part of shift patterns, with drivers similarly knowledgeable about how this fits in with their other driving duties. Within the legal limits it is possible to drive 13 days out of 14, of which some of the participants have experience. This necessarily cuts down on rest periods; some drivers commented on these not being long enough in terms of sleeping sufficiently well.

There is a general shortage of part-time bus drivers, with some companies having none at all. The focus group participants suggested that a greater number of such workers would reduce fatigue, and perhaps attract a greater number of people to the profession; this was felt to be necessary given the current shortage of drivers in London.

Overrunning shifts were cited as a particular cause of fatigue, where a driver might be delayed significantly due to traffic and/or diversions. This can then reduce meal relief periods. Drivers are concerned when they lose stand time and when this is curtailed or even cut due to the short turnaround times which are sometimes a result of the current pressure on the schedules or unexpected delays (caused, in part, by buses and routes being taken out of service). They also see an increasing pressure to arrive early to work (often unpaid) in order to check the bus before departure, demonstrating a need to maintain buses to ensure they are always kept in a suitable condition.

'Spread-overs' (12-hour shifts which include a 3 to 4-hour break in the middle) have formerly been common, however the focus groups showed that a relatively low number of the operating companies currently utilise these. Drivers noted earning more for such shifts but finding them fatiguing when having to stay at the garage or depot during the break or as a result of the extension of work time and shorter periods away from work overnight. It is notable that such drivers stated they would be likely to sleep during these breaks if the appropriate facilities exist.

3.3.1.9 Sickness

The theme of sickness was clear throughout the focus groups, with examples cited of fatigue and stress causing drivers to be unwell (depression, heart attack, stroke, obesity etc.). It was also suggested that fatigue weakens the body so that drivers are more susceptible to colds and other more minor ailments. Unhealthy eating patterns were also believed to be a cause of some of these illnesses and fatigue. One participant had experience of sleep apnoea, which had been medically managed in conjunction with the operator, enabling them to continue driving.

In all of the operating companies the responsibility is on drivers to declare their fitness to work when signing on for duty. This may be in a variety of ways and is more explicit in some companies than others. Drivers were all aware of how to report in sick but were wary of doing so due to strict rules surrounding absences from duty. This is related to having to speak to a manager if absent three times within a circumscribed period, with a note being added to the driver's personal file. The

participants did not see this as a means of discussing any problems they might have but were more concerned about what they see as a disciplinary procedure.

One focus group was vocal about requiring a greater level of welfare support. This had been provided to them in the past, and they believe it would be a valuable support in discussing and managing their fatigue.

3.3.1.10 Sleep

As noted elsewhere, effective and sufficient sleep is recognised by the participating bus drivers as key to avoiding tiredness, and they recognise the differences and links between mental and physical fatigue. There were widespread examples of feeling tired or drowsy whilst driving, with varying severity, as far as to name instances of drivers falling asleep or having microsleeps whilst at the wheel. This is not common but has happened.

Participants acknowledged a difference in their driving when fatigued and the key effects were: speeding up, driving erratically, driving on autopilot, longer reaction times, failure to think and plan ahead, losing concentration, and driving aggressively. Drivers were aware of the possibility of making a simple mistake and causing an incident due to fatigue. A clear link between tiredness and collisions was recognised by the participants. In addition, fatigued drivers might become miserable, not smiling or wishing to speak to the passengers.

Some drivers noted having difficulties relaxing and sleeping in between shifts and had experiences of falling asleep at home when undertaking a different task.

3.3.1.11 Stress, workload and frustration

As noted above, drivers linked 'stress' (by their own definition) and fatigue during the focus group discussions, with some mentioning stress when asked to define fatigue. They named the following as significant causes of what they would describe as stress:

- The monotony of driving the same route; some have altered their shifts in order to vary the routes driven
- Passengers lacking respect for the drivers, complaining about the late running of the bus, not acknowledging the driver, not paying for their journey, making (unjustified) complaints after travelling on the bus
- School children – mentioned particularly as challenging and stressful for the drivers due to riding on the bus in groups and incessantly pressing the stop button
- Radio and controllers– the communication between the radio controllers and the bus drivers can be problematic, with drivers complaining about the tone sometimes used to give them information/instructions. The drivers believe that the majority of the controllers have not been employed as drivers and are therefore not empathetic; it is likely that this is an inaccurate assumption. Requests made by controllers (wait for five minutes, terminate the bus) cause passengers to blame the drivers. The condition of the radio can also be bad and therefore distracting and stressful
- Internal and external monitoring including 'mystery travellers' and the Best Customer Experience survey which they see as adding further duties (e.g. pulling up to the stop properly, greeting all passengers) when driving in often demanding situations
- A lack of support from their employer, e.g. feeling unable to report fatigue and two participants (in different focus groups) noted receiving a letter at the beginning of their shift requesting they have a meeting with a manager; they subsequently dwelt on this for the remainder of their duty

- Other road users (see 3.3.1.6)
- Threats and violence from those inside and outside of the bus, that is, being abused by the public, vulnerability of opening the cab window, using the safety screen as a deterrent but then finding it a barrier to interaction with passengers
- Information overload – having to concentrate on passengers, the traffic situation and the controllers all at one time
- The physical environment, that is, the condition of the bus itself, the physical discomfort of driving a bus, and experiencing a problem with the bus before leaving the depot
- Having had an incident whilst driving the bus, some drivers find it very difficult to forget about it
- The pressure and difficulties of meeting the route timetable which is often unrealistic

The drivers' methods of avoiding stress and relaxing were socialising with colleagues, exercising and practising methods of staying calm. A dedicated stress policy at operating companies was noted as a potential benefit.

3.3.1.12 The occupation of 'bus driver'

The focus groups were notable for raising some specific issues related to bus driving as a specific and distinctive occupation. Several of the groups believe that bus drivers are key workers, keeping London moving and working, particularly when other public transport is not available. For example, bus drivers notice a difference when underground train workers are on strike, and they are required to act as a replacement and take on a greater volume of passengers. Furthermore, participants compared themselves with underground drivers, suggesting that driving a bus is a more complex occupation, which involves a far greater level of interaction with passengers and lower levels of pay. Some stated a wish to become employees of TfL, in a similar manner to underground drivers. A more active union was cited as being required to aid in an improved working situation for bus drivers. Some participants had been employed to drive a coach or truck and claimed that working on a bus is more fatiguing. However, the participants were also often positive about their jobs, saying that they carried on as a bus driver due to an enjoyment of, or even passion for, driving. Others noted enjoying the interaction with people, which they prefer to an office job.

The theme of bus driving being a specific activity was widely discussed, with suggestions that drivers are taking on a greater number of duties and becoming operators rather than simply drivers. Indeed, the notion that bus drivers hold a high level of responsibility was universally understood, with participants noting their heightened feelings of accountability for other people's safety whilst driving a heavy vehicle full of passengers. There was also a constant feeling of being responsible for delivering a service to the public which they want to continue without being subject to delay.

All of the focus groups noted a lack of respect for bus drivers; this relates to stress received from dealing with passengers and, to a certain extent, cyclists. Participants felt the need to note that drivers are people with feelings, with one group going as far as to suggest a public education programme on not stressing (and therefore fatiguing) drivers. The drivers suggested that they would like their situation to be understood by managers and to take into consideration that "we are human beings, we have a body clock, we have families." Participants therefore sometimes have feelings of loneliness through a lack of social contact, both from being ignored and/or disrespected by passengers and due to working unsocial hours. Individual differences between driver personalities was discussed in relation to this, with some feeling more fatigued than others by disagreeable or indifferent passengers.

The policy review completed for this research showed that the ratio of females amongst London bus drivers is currently approximately 10%. Female participants stated that this can present difficulties for women drivers in that they feel a lack of companionship and difficulties in discussing any issues particular to females.

As noted above, there were participants in the focus groups who had a long history working as bus drivers and some of these compared their current working lives with their past situation. A strong feature of these comments was a feeling of nostalgia, whereby they felt that their past experience was more positive than their current circumstances.

3.3.1.13 Time of the day

There was a range of times at which drivers reported being most likely to feel fatigued. There were as follows: at the beginning and the end; in the middle; coming towards the end; after a break having eaten; the first day back after rest days; at the weekend; at rush hour; sitting around during spread-overs and early jobs that begin around 3.00am. Several of the drivers noted that they have shifts during which their break is early into the shift, meaning that the second half is comparatively much longer (2.5 hours/5.5 hours) – they feel particularly fatigued during the second half. Longer and busier routes were also reported to lead to greater levels of tiredness.

3.3.1.14 Work life home life

Drivers discussed the difficulties of balancing their work and home life, and how this can lead to feeling tired. For example, drivers interested in overtime can be contacted by their employer whilst at home and this can often interrupt them whilst they are actually asleep. This is clearly not ideal for effective sleep patterns.

Many of the participants discussed family and social commitments as important contributors to fatigue. They noted that their non-working time is often taken up with the needs of their families, causing them to miss out on rest, relaxation and sleep time. This may be due to children, spouses and parents requiring their attention. It is particularly striking that drivers may have only a 10-hour period between shifts, during which they must, for example, travel between work and home, cook and eat some food, relax, spend time with their family and, most importantly, sleep. Many participants noted finding this problematic. This was also true when considering social commitments which might cause drivers to stay up late, therefore lacking sufficient sleep for a subsequent shift. This was particularly the case for younger drivers.

Various methods of relaxing at home after work were noted by the participants, most importantly a recognition of the importance of sleeping. Other methods were spending time with the family, watching television, playing computer games, cleaning, watching horror films, and not thinking or talking about their work. These are ways the drivers find to help them have a healthy sleep pattern. The discussions also found that some drivers experience difficulty relaxing between shifts, which may lead them to have insufficient or poor sleep.

Methods of relaxing before work included arriving as early as possible and socialising with colleagues, relaxing and eating in the canteen, watching the television, and trying not to get stressed by doing something they enjoy. Others suggested they simply get themselves ready, drink some coffee and go.

3.3.2 Summary

In summary, the focus groups demonstrated the following:

- Fatigue is a problem amongst participants in the focus groups, with all of the participants having experience, or being aware of others having experience of sleep-related incidents whilst driving a bus
- Drivers are unlikely to discuss fatigue amongst themselves, or with their managers and generally avoid reporting it, preferring to report in sick
- Levels of overtime are high amongst London bus drivers, mainly cited as being a response to low levels of pay; opportunities for overtime are great due to the current lack of drivers
- Family and social commitments contribute to levels of fatigue amongst participants in the focus groups
- Shift patterns are believed to be a key issue in fatigue; this includes rota patterns, scheduling and break length
- A general lack of facilities (including for breaks) is a concern for the bus driver participants
- Bus drivers recognise the responsibility inherent in their job, but also see a lack of respect for their role amongst those with whom they interact
- Stress is seen as a cause of fatigue by the participating bus drivers; stressors include passengers, other road users (including traffic), monitoring and the condition of vehicles

3.4 Task 4: Manager interviews

All ten of the London bus operating companies nominated managers suitable to be interviewed in relation to fatigue management. That is, a person who would respond if a driver reports feeling tired, or if a driver has an incident appearing to be caused by fatigue/sleepiness. In total, 11 one-to-one telephone interviews were conducted by the same researcher (two individuals were involved from one operator; one at each of the remaining nine operators). Of the 11 interviewees, 10 had previously worked as a bus driver before becoming a manager.

3.4.1 Key findings

The interviews showed that the managers have a greater understanding of the drivers than the drivers in the focus groups think; this empathy is likely to be due to the fact that the majority of interviewees had worked as a driver earlier in their career. Managers are in some ways caught in the middle between drivers and the needs of the operator because there is a requirement to keep the buses moving and to guard the operator's reputation. To the managers, fatigue is a safety issue and they feel the responsibility to make sure it is not having an adverse impact on the business or risking people's lives. From the management perspective it is necessary for supervisors and managers to know how to spot the signs of fatigue and question it and challenge it and make sure the people who are driving their buses are fit to do so. On the other side there is a need to make sure the staff are aware of fatigue issues and that they are actively managing it themselves taking into account their sleep patterns and what they do during the day and what they do before and after. Therefore, drivers have the responsibility to manage their fitness but also their fatigue levels. There is an understanding amongst managers that bus driving is a responsible job which drivers should take seriously because it is a safety critical role.

There was a general recognition that fatigue is a concern amongst London bus drivers, and all of the interviewees had seen examples of it being a contributing factor to incidents on the road. The extent to which fatigue is a problem was disputed amongst the managers interviewed, but not all were as involved in investigating incidents and/or fatigue as others. In addition, it is notable that managers commented on suffering from fatigue themselves, and utilising similar countermeasures to those discussed by the drivers.

As might be expected, individual differences exist between the managers in terms of how understanding they are about the fatigue which bus drivers exhibit, and how approachable they aspire to be. Several of the managers raised the subject of random testing for drugs and alcohol, when asked about how they ensure their employees are fit to drive, although they recognised this was not necessarily an indicator of fatigue. One manager noted informing drivers that being awake for 17 hours can impair performance to the same degree as two units of alcohol as a means of explaining the impact of fatigue.

Overall, seven of the 14 key themes identified in the focus group analysis were discovered in the manager interviews.

3.4.1.1 Commuting

None of the operating companies have a policy or restriction on commuting distance to work, and managers are aware that some drivers have a long journey before they sign on for duty. They are aware that this can add to fatigue and some mentioned either speaking to employees about this or monitoring those to whom it applies.

3.4.1.2 Definitions and understanding of fatigue

In order to reinforce the project's definition of 'fatigue', the managers were asked to explain their understanding of the term at the beginning of each interview. The first response was generally 'tired' or 'tiredness', with the added suggestion of "tiredness to the point of feeling drowsy, you want to go to sleep." Monotony caused by heavy traffic, lack of sleep and the time of a shift were also mentioned here. The interviewees also connected feelings of moodiness, agitation, difficult passengers and stress to fatigue. However, they found it difficult to suggest any other potential causes of fatigue.

In common with the drivers, the managers understood the difference (and links) between physical and mental fatigue. They were more likely than the drivers to link tiredness explicitly with lack of concentration, crashes and falling asleep at the wheel.

3.4.1.3 Money

The managers all discussed having a shortage of drivers, leading them to offer relatively high levels of overtime to existing employees. They generally realise this could be leading to drivers taking on too much work, but their responsibility to the operator and knowledge of driver's own wishes outweigh those concerns.

Another reason for overtime cited by the interviewees was the low levels of pay that drivers experience. They see this as a result of the tendering process in which companies endeavour to keep costs as low as possible. Drivers will therefore take on extra duties to make up their money. Two of the managers also suggested that the current low rates of pay are attracting people who are not particularly suitable to act as drivers.

3.4.1.4 Reporting fatigue

Managers all place the emphasis and responsibility on the drivers to ensure that they are avoiding fatigue. They state that companies are eager to support drivers in their efforts in this area but cannot force them to take the appropriate measures. However, all of the managers were positive about trying to help and support drivers if they report fatigue; the frequency of reporting was not discussed in detail. They try to be approachable and open, desiring an open culture around tiredness issues, although all noted that the operators could be more proactive in their efforts to highlight fatigue and promote a greater level of openness around the subject. Moreover, managers recognise

that the drivers are reluctant to report fatigue, fearing disciplinary action. They believe that drivers will either continue working although fatigued, or report in sick rather than admit to tiredness.

An example of this willingness to be supportive came from an interviewee desiring information from the research study to help in these endeavours. Information requested related to the least fatiguing kind of shift patterns in order to offer these to drivers, and examples of advice that could be offered to drivers for reducing fatigue. One manager had put together a handout and presentation on their information screen for drivers because awareness of fatigue had been raised by some incidents. This was intended to educate drivers on the risks of fatigue and how to manage it. Another manager had been doing some research of their own about driver fatigue.

The emphasis is also on drivers to report fatigue so that they can receive help. In an incident which was found to be due to fatigue, a driver who had not reported tiredness would be more likely to be disciplined and sacked.

The managers also discussed the difficulty of proving tiredness in an incident. In all companies there are investigations of incidents, with procedures and questions asked, including some related to sleep, shift patterns, overtime and fatigue. In addition, many of the managers were responsible for watching recordings of drivers in incidents. Some had gained a knowledge of the signs of potential fatigue but noted it can be impractical to be sure that it has been in play.

3.4.1.5 Shift patterns

It was widely acknowledged by the interviewees that shift patterns can be a major cause of fatigue, especially when considered alongside the elevated levels of overtime being undertaken. Some of the solutions offered by managers are as follows:

- Overhauling and altering rotas in response to drivers reporting fatigue
- Accommodating driver requests by attempting to arrange shift patterns around the preferences of employees
- Instituting longer rest periods between duties than are stated within the legal limits – this is a company-wide initiative in one instance
- Putting drivers on one shift pattern (‘constant shifts’) to help when they report fatigue
- Putting drivers on a more stable shift pattern when they report fatigue
- Allowing drivers to swap shifts for a period (usually 2-3 months) to alleviate monotony

One manager noted that they believe the operator’s safety and scheduling teams are not working together to the extent they could. This might aid in the creation of safer shift patterns.

3.4.1.6 Sickness

The interviewees had encountered a variety of health issues related to their drivers. More generally, some managers noted finding it unhealthy to be working long hours (e.g. thirteen days as is legally permissible) and cited it as a big problem in terms of the health of the drivers.

When the drivers tell them about insomnia or other sleeping problems the managers report being able to involve occupational health and medical staff and ensure their shift patterns are appropriate, e.g. avoiding early starts and focusing on later shifts. This helps to ensure drivers are getting the appropriate rest and sleep. Medical intervention may also reveal other underlying health issues such as sleep apnoea; examples of which most of the managers had encountered. Driver health is utmost with the managers who want to ensure they adopt a healthy lifestyle through resting when not at work, getting plenty of sleep and having a healthy diet.

3.4.1.7 Work life home life

The managers recognise drivers have a life outside of work and noted that family and other commitments are likely to affect their ability to have sufficient sleep and are therefore a contributory cause in levels of fatigue. They also acknowledge that the younger drivers may have social commitments which also reduce their levels of sleep.

3.4.2 Summary

In summary, the manager interviews demonstrated the following:

- The interviewees recognise fatigue as a problem amongst the drivers they supervise and they understand the links and differences between mental and physical fatigue
- Many of the managers interviewed demonstrate a wish to make fatigue a more acceptable subject to discuss and would welcome a more open culture around this subject
- Given their understanding, managers are agreed that the responsibility lies with the drivers to manage and report their own fatigue
- Managers are making attempts to mitigate against fatigue by responding to the needs of the drivers when fatigue is reported to them
- Managers have a responsibility to drivers and the needs of the company; to the managers, fatigue is a safety issue and they feel the responsibility to make sure it is not having an adverse impact on the business or risking people's lives
- Managers recognise the other pressures on the drivers outside of the work context

3.4.2.1 A comparison of the findings of the bus driver focus groups and the manager interviews

In comparing the findings from the driver focus groups and manager interviews the following similarities and differences were observed:

- Participants in both the focus groups and interviews are agreed that fatigue is a concern for London bus drivers. They have a similar level of understanding of mental and physical fatigue, and on the ways in which these manifest
- There were differing views on reporting fatigue, with managers wishing to be open and approachable so that drivers can feel comfortable in talking to them about being tired. Conversely, drivers generally would avoid reporting being fatigued, fearing disciplinary consequences
- It could be argued that the managers are more apt to understand the perspectives of the drivers than the drivers are to be understanding about the views of the managers
- There is agreement across the two work roles that shift patterns are a key cause of tiredness, and that these might therefore be improved
- Managers and drivers both agreed that overtime is contributing to levels of fatigue, but both had their own reasons for seeing a necessity for it currently
- It could be argued that managers would benefit from a greater knowledge about the causes of fatigue, particularly in regard to the lack of facilities, as this was commonly mentioned by drivers but not by managers. That is, when the interviewed managers were asked what contributes to fatigue, they were less likely than the drivers to discuss the lack of facilities
- It was clear that the first concern of managers is safety and they were therefore more likely than the drivers to link tiredness explicitly with lack of concentration, crashes and falling asleep at the wheel

3.5 Task 5: Driver survey

3.5.1 Key findings

This section discusses the key findings obtained from the bus driver survey. In total, 1,353 drivers completed the survey (85% male). Drivers were aged between 20 & 73 years, with an average age of 45 years, and had been driving a bus for an average of 10 and a half years. Approximately 46% worked on fixed rotas, and 52% worked on rotating/ mixed rotas. Drivers reported working between 8 and 75 hours per week (average of 44 hours per week). On average, drivers reported needing 7h 55m (*SD* = 1h 8m) sleep between shifts to be able to drive safely and feel rested. However, they usually got an average of 6h 30m (*SD* = 1h 20m) sleep between shifts.

At least one driver from each of the 10 London bus operators responded to the survey. However, it should be noted that 1,353 drivers is a small proportion of all London bus drivers (total = ~25,000). A full list of results obtained in this survey can be seen in Appendix I.

3.5.1.1 The extent and nature of fatigue in London bus drivers

The first set of results address the research question "what is the extent and nature of fatigue in London bus drivers?". The results from the survey show that drivers do experience sleepiness and fatigue whilst driving the bus. 79% of drivers who responded to this survey believe that their working hours lead to sleepiness whilst driving the bus. A large percentage of drivers indicated that they experienced signs of sleepiness such as yawning (89%), frequent eye blinks (53%), and difficulty concentrating (41%) whilst driving the bus (see Figure 3.2).

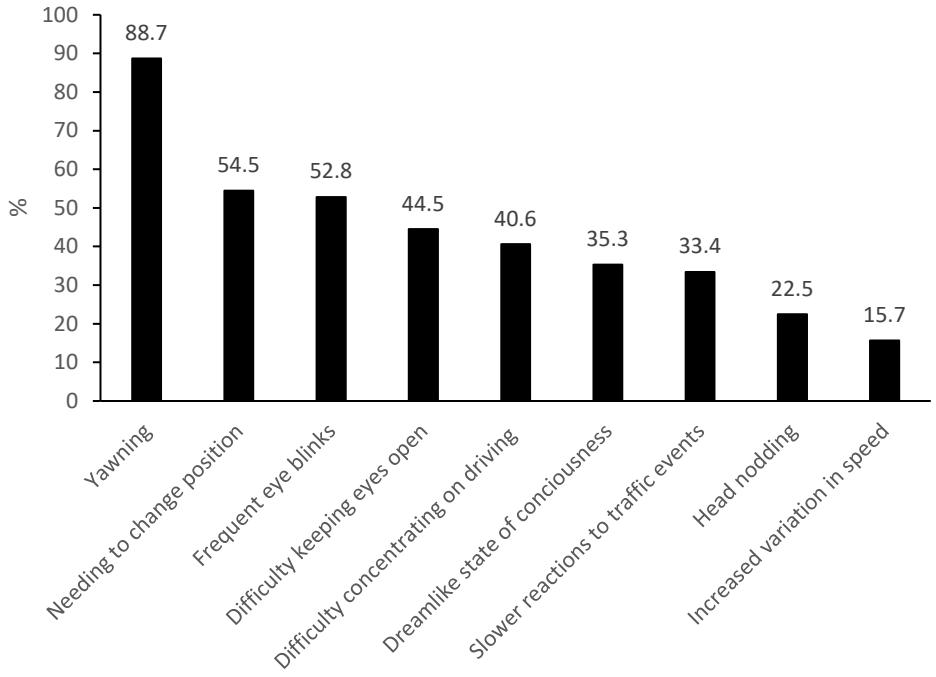


Figure 3.2: The percentage of respondents who said they showed signs of sleepiness whilst driving the bus. Respondents were able to select more than one option.

When looking at the effects of sleepiness and fatigue whilst driving, approximately 17% of drivers indicated that they had fallen asleep whilst driving the bus at least once in the past 12 months (see Figure 3.3).

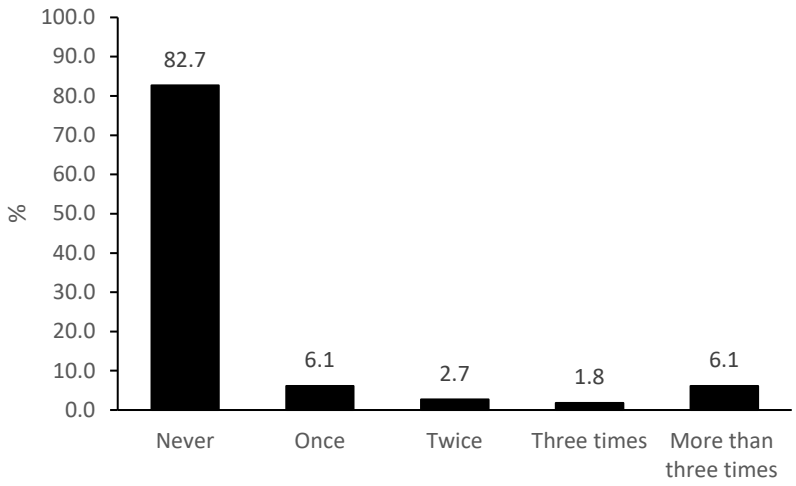


Figure 3.3: Frequency distribution for "In the past 12 months, have you fallen asleep whilst driving the bus?"

When asked if they had experienced a road crash or a close call in the past 12 months due to fatigue, approximately 5% of drivers reported being involved in a road crash at least once, whilst approximately 36% of drivers reported having at least one close call in the past 12 months (see Figure 3.4). Operators and TfL are likely to be unaware of the effect of fatigue and sleepiness in these circumstances because 77% of those who had experienced a road crash believed their employer did not know the incident was due to the driver feeling sleepy. A similar result emerged amongst drivers who experienced a close call, with 88% indicating that their employer would not know the incident was due to them feeling sleepy.

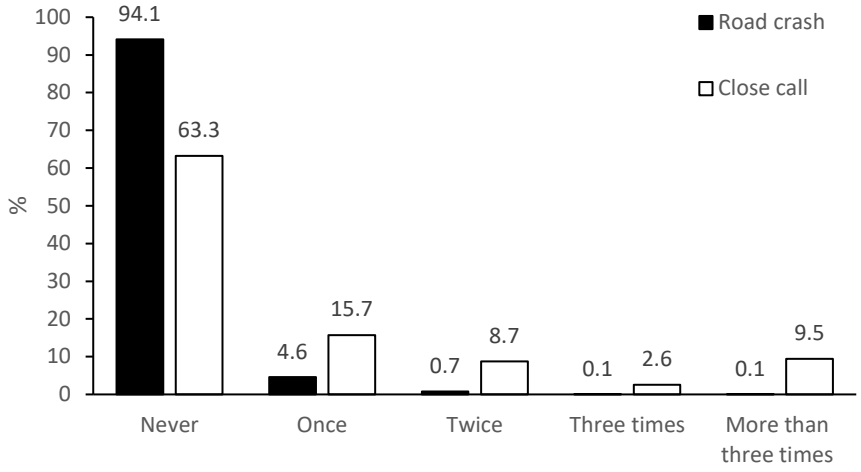


Figure 3.4: Frequency of drivers reporting being involved in a road crash or close call in the past 12 months because they were sleepy.

Further evidence to suggest that bus drivers experience fatigue can be seen in the responses to questions relating to stopping the bus due to fatigue. Drivers were asked if they have had to stop the bus due to fatigue in the past 12 months, and if they had wanted to but were unable to. The results showed that whilst 78% of drivers had never had to stop the bus, more than half (55.5%) had wanted to at least once, with 28% of drivers wanting to stop the bus due to fatigue more than three times in the past year (see Figure 3.5).

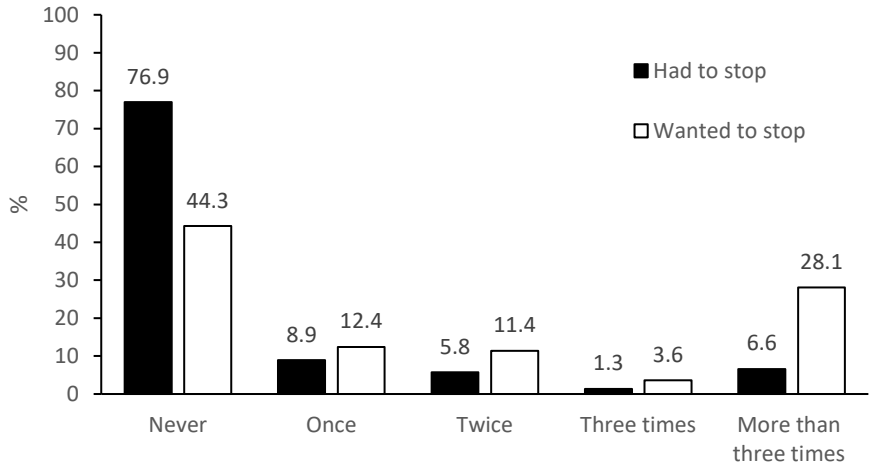


Figure 3.5: Percentage of drivers stating that they had to or wanted to stop the bus in the past 12 months due to fatigue.

In response to the question "how often do you have to fight sleepiness in order to stay awake while driving the bus?" 21% of drivers indicated that they have to fight sleepiness at least 2-3 times a week (see Figure 3.6). This result was similar to that of the Swedish survey by Anund et al. (2016) who found that 19% of drivers had to fight sleepiness at least 2-3 times a week. The variable of having to fight sleepiness was related to several variables referring to sleepiness/ fatigue related incidents on the road. Results showed that having to fight to stay awake at least 2-3 times a week was a significant predictor of falling asleep whilst driving the bus with those who had to fight sleepiness being 5.5 times more likely to have fallen asleep whilst driving at least once. Those who had to fight sleepiness were also 6.5 times more likely to have had a close call, and almost 3 times as likely to have had a road crash in the last 12 months. They were also twice as likely to have had a sleep related incident in the last 10 years. These results were obtained from conducting a series of univariate logistic regressions.

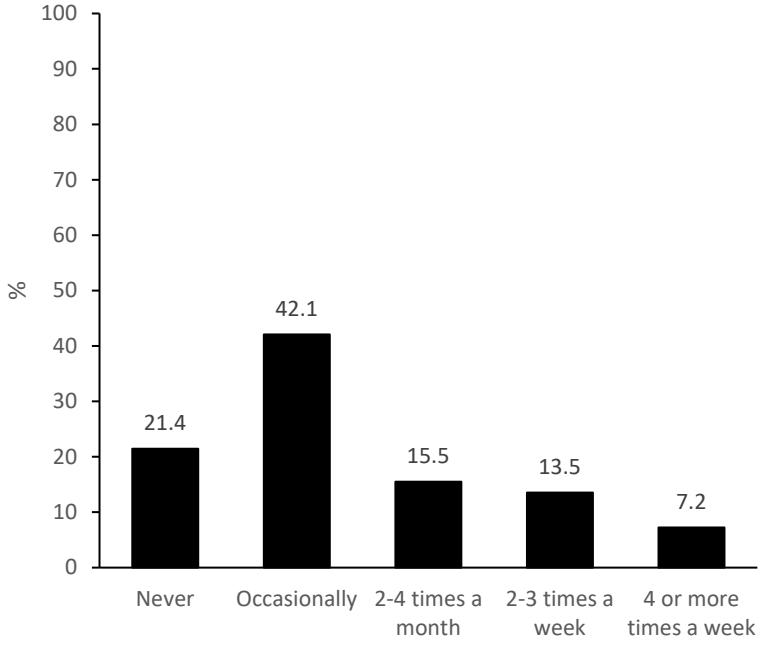


Figure 3.6: Frequency distribution for "how often do you have to fight sleepiness to stay awake while driving the bus?"

3.5.1.2 The key causes of fatigue in London bus drivers

This section addresses the research questions "What are the key causes of fatigue?" and "Are there patterns of working, demographics or any other factors that are correlated with fatigue in London bus drivers?" From the survey results it is possible to identify which factors are statistically associated with driver fatigue/ sleepiness. In order to achieve this, drivers have been grouped according to two criteria. Those in the first group had to fight sleepiness whilst driving the bus at least 2-3 times a week (*n* = 281), and those in the second group did not (*n* = 1069). For the second criteria, those in the first group had experienced a sleep related incident in the last 10 years (*n* = 227), and those in the second group had not (*n* = 1076).

Statistical analyses were used to first determine whether individual variables were able to predict whether a person would have to fight sleepiness, and whether they had a sleep related incident in the last 10 years. The variables used in these analyses were split into three categories: (1) sleep related factors, (2) work related factors, (3) health related factors. The analyses can be seen in Appendix J. Predictors which were found to be statistically significant were then entered together into a further analysis to establish which factors were the strongest predictors of either having to fight sleepiness or having a sleep related incident.

Several factors were found to be significant predictors of whether or not drivers had to fight sleepiness at least 2-3 times a week. In relation to sleep, scoring highly on any of the sleep indices was a strong predictor, with those scoring highly being significantly more likely to have to fight sleepiness than those who scored lower. Another strong predictor was having a sleep condition, with those who had a sleep condition being three times (200%) more likely to have to fight sleepiness than those without a sleep condition (with the majority of those reporting a sleep condition reporting obstructive sleep apnoea). Not obtaining enough sleep was a strong predictor or having to fight sleepiness, respondents who reported not getting enough sleep before their shifts were three times (200%) more likely than those who reported getting enough sleep. Respondents who snored were 85% more likely to have to fight sleepiness. Self-reported sleep quality was also a significant predictor, with those reporting good sleep quality being 80% less likely to have to fight sleepiness than those who reported poor sleep quality. These results were similar to those obtained in the Swedish bus driver survey by Anund et al. (2016), where scores of each of the five sleep indices, snoring, and obtaining enough sleep were al found to predict having to fight sleepiness. Previous work by Kim et al. (2018) has also shown that having a sleep disorder significantly predicts driver fatigue.

Work related factors were also found to influence whether drivers had to fight sleepiness. Those who had less than 11 hours' break between shifts were 45% more likely to have to fight sleepiness, whilst those who reported working for more than 6 consecutive days without a rest day were 80% more likely. Drivers receiving short notice of shifts were 60% more likely to have to fight sleepiness, and drivers who experienced variability in start times were 80% more likely. The amount of stress experienced whilst driving the bus was also a significant predictor, with drivers who rated their stress as higher being 30% more likely to have to fight sleepiness. Commuting was an important factor, and results showed that those who had longer commute times were slightly more likely to have to fight sleepiness, whilst those who commuted using public transport were 25% less likely than those who did not. One work related factor which was not found to be a significant predictor of having to fight to stay awake was whether the respondents worked rotating or fixed rosters.

Two of the strongest predictors of having to fight sleepiness were specifically related to break times at work. Drivers who reported having insufficient time to eat were twice as likely (100% more likely) to have to fight sleepiness than those who reported having sufficient time. Whilst drivers who

reported having insufficient time to rest during their break were more than twice as likely (170% more likely) to have to fight sleepiness than those who reported having sufficient time. Another significant predictor related to breaks at work was having somewhere to sit, drivers who were not provided with somewhere to sit during their breaks were 65% more likely to have to fight sleepiness than those who reported having access to somewhere to sit.

One final work related factor which significantly predicted not having to fight sleepiness was enjoyment from bus driving, with those who stated that they drove for enjoyment, as opposed to just for payment, being 20% less likely to have to fight sleepiness.

In terms of health factors, self-reported health was a strong predictor of having to fight sleepiness. Compared to those reporting good general health those reporting their health as neither good nor bad were 80% more likely, whilst those reporting poor health were over three times (230%) more likely. Those who indicated that they had experienced higher levels of stress over the last 3 months were 30% more likely to have to fight sleepiness. Those who smoked were also 40% more likely to have to fight sleepiness. Neither BMI, nor level of exercise were found to be significant predictors of having to fight sleepiness.

Age was also a significant predictor such that drivers in their 20s were more likely to have to fight sleepiness. In comparison, drivers in their 40s and 50s were 50% less likely, whilst those aged between 60 and 73 were 60% less likely. The previous Swedish survey (Anund et al., 2016) did not find any differences between drivers of different ages, however research on truck and car drivers has shown that drivers who experienced fatigue related incidents were younger than those who did not (Summala & Mikkola, 1994). Gender and socio-economic status (as determined by the multiple deprivation index) were not significant predictors of having to fight sleepiness.

Results relating to factors which predicted having had a sleep related incident in the past 10 years were similar to those predicting having to fight sleepiness, with the exception of the following. Roster type now emerged as a significant predictor, with those on rotating rosters being 40% more likely to have had a sleep related incident than those working fixed rosters. This is unlike the results for having to fight sleepiness in which roster type was not found to be a significant predictor. However, it should be noted that roster type was not a highly significant predictor, and other variables were better able to distinguish between those who had and had not experienced a sleep related incident. A further discussion relating to scheduling can be found in section 4.4.

Late running of buses also now emerged as a strong predictor, with those who experienced late running at least once a month being around 3.5 times (245%) more likely to have had a sleep related incident in the last 10 years. Those who worked longer hours were also more likely to have had an incident than those who worked fewer hours.

Several factors related to work did not emerge as significant in the regressions relating to having had a sleep related incident in the last 10 years, these include: factors relating to breaks during shifts, commuting, and short notice of shifts. This is likely to be because the question relating to sleep related incidents referred to incidents whilst driving the bus or their personal vehicle, therefore incidents may not have occurred whilst working as a bus driver.

Following the initial set of analyses, any factors which were found to be significant predictors were entered together into a further analysis. The purpose of this analysis was to establish which factors were the strongest predictors of either having to fight sleepiness or having a sleep related incident. Five predictors emerged from the model pertaining to having to fight sleepiness, these were; the sleepiness index, the impaired waking index, enjoyment from bus driving, commuting using public

transport, and self-reported sleep quality. With these predictors, this model was able to correctly classify 80% of the cases.

The analysis relating to the outcome of having a sleep related incident in the last 10 years produced a model containing two predictors (the fatigue index and enjoyment from driving) and was able to correctly classify 79% of cases.

3.5.2 Summary

In summary, the survey demonstrated the following:

- Fatigue and sleepiness is a problem for London bus drivers, although fatigue related incidents are under-reported
- Drivers are having to fight to stay awake whilst driving the bus
- Fatigue is caused by a variety of factors related to sleep, work and health. Some of the biggest contributing factors are:
    - Fatigue and sleepiness during the day
    - Shift related issues
    - Insufficient break times/ facilities
    - General driver health

3.6 Task 6: On-road observation

3.6.1 Key findings

Due to practical and technical problems (including the complexity of planning the study, recruiting drivers, and using a specifically equipped bus on a specific route), data from between 12 and 16 drivers are included in the analysis of questionnaires, diaries, sleep pattern and effect on driving behaviour, sleepiness and stress while driving.

3.6.1.1 Background questionnaire

All the participants were full-time bus drivers and had been in the occupation for 11 years on average (range 3 to 17 years). They were on both fixed and rotating rosters. Enjoyment from driving and perceived stress was reported on a scale where 1 is low and 10 is high. The drivers reported high enjoyment from bus driving (mean 7.9, range 4 to 10). Their daily stress level while driving was 3.7 (range 1 to 8) and the general stress level the last three months was 3.3 (range 1 to 10). The drivers reported good health in general (6 very good, 8 quite good, 2 neither good nor bad health). Drivers commute time ranged from 15 minutes to 1 hour 45 minutes, with an average commute time of 50 minutes to and from the depot.

There were no indications of general sleep or fatigue issues among the drivers according to the KSQ (see section 2.5.2). The five sleep indices created from the KSQ (index range from 1-6 and >5 indicates problems) had an average between 1.4 and 2.1 in this group of drivers and none of the drivers had index values above 4. A general question about sleep in the last three months revealed that three drivers had ‘very good’ sleep, eight had ‘quite good sleep’, four had ‘neither good nor bad’ sleep and one had ‘quite bad’ sleep. Eight drivers reported that they never had to fight sleepiness while driving the bus, whereas six drivers reported that it happens occasionally, and two drivers reported 2-4 times a month.

3.6.1.2 Diary results

Results from the sleep and wake diaries were compared between rest days (n=16) and days when the drivers were working morning (n=28) or daytime (n=41) shifts. The drivers reported significantly less sleep before early morning shifts (mean 6h 36 min) compared to rest days (mean 8h 6min) and daytime shifts (mean 8h 1min) (see Figure 3.7). Since the drivers reported their bedtime and wake-

up time, this is a measure of total time in bed and not only time spent asleep. A general question about sleep the previous night, ranging from 1=very bad to 5 =very good, revealed that the drivers slept well most nights; 74% of the nights were rated level 4 or 5, 18% were level 3, and 8% level 1 or 2.

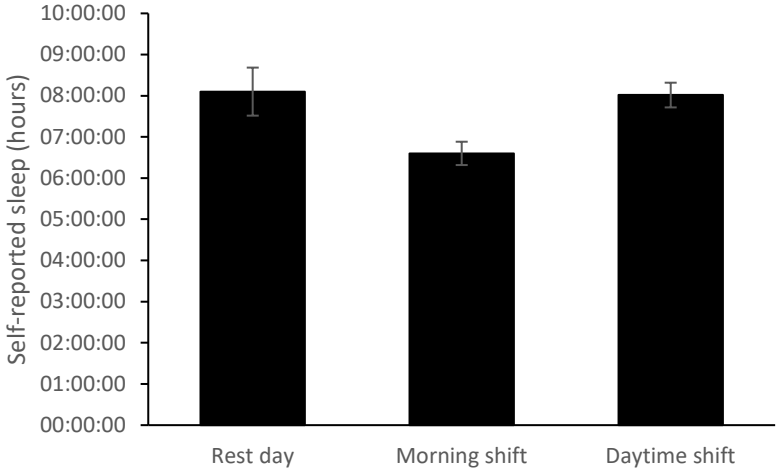


Figure 3.7: Self-reported sleep. Error bars represent standard error of mean (SEM)

In 16% of the work days, drivers reported having to fight to stay awake while driving (5% of morning and 11% of day shifts). In 12% of the days, drivers were feeling so sleepy that it was difficult to be alert or focused enough (1% of morning and 11% of day shifts). In 17% of the days, drivers felt the need to take countermeasures to stay awake (5% of morning and 12% of day shifts). Due to the low number of entries, it was not possible to statistically test differences between morning and daytime shifts.

3.6.1.3 Sleep patterns

The bus drivers slept significantly less, expressed as total sleep time (TST), the night before the morning drive (average TST 4h 51min) compared to the daytime drive (average TST 6h 12min) (see Figure 3.8). This pattern of significantly less TST before the early morning drives remained when TST was averaged over four days before each drive (see Table 3.5). None of the 14 drivers slept the recommended 7 hours (Hirshkowitz et al., 2015) the night before the morning drive. Before the daytime drive, only four out of 15 obtained at least 7 hours sleep. This can be compared to the results from the background questionnaire, where the drivers reported that they needed 7.5 hours of sleep per night to feel rested (range 5 to 12 hours).

Table 3.5: Sleep data derived from actigraphy. Significant results in bold.

	Morning			**Daytime**			
	Mean	Min	Max	Mean	Min	Max	p-value
TST (hh:mm)	4:51	2:08	6:31	6:12	3:56	8:55	**0.009**
SE (%)	77.84	58.99	90.51	80.26	56.46	91.41	0.126
SOL (min)	17	0	77	9	0	57	0.338
4 day mean TST (hh:mm)	5:34	3:52	7:03	6:14	3:07	8:08	**0.037**
4 day mean SE (%)	78.66	56.42	90.02	79.32	44.15	93.71	0.761
4 day mean SOL (min)	11	1	26	14	1	46	0.455

TST=total sleep time, SE=sleep efficiency, SOL=sleep onset latency.

There were no significant differences in Sleep Efficiency (SE) and Sleep onset latency (SOL) between the days before the morning and daytime drives (see Table 3.5). Sleep efficiency below 85% is generally considered poor. Eleven out of 14 drivers had poor SE the night before the morning drive and 10 out of 15 drivers had poor SE the night before the daytime drive.

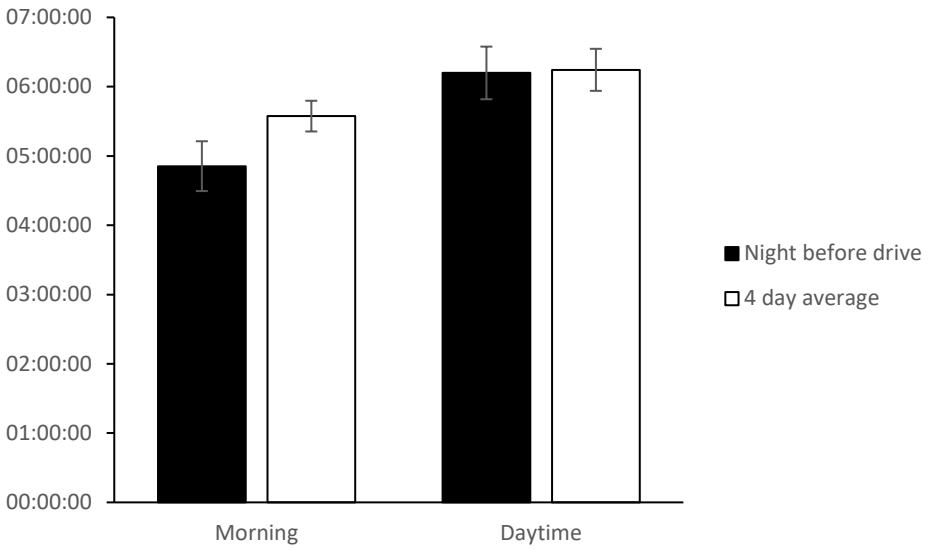


Figure 3.8 Total sleep time. Error bars represent standard error of mean (SEM)

3.6.1.4 Sleepiness, stress and driving behaviour

Comparison was made between the data recorded for morning and day time drives. Sleepiness measured with the Karolinska Sleepiness Scale (KSS) was significantly lower during morning (mean 3.24; SD 1.21) compared to daytime (mean 3.57; SD 1.79) driving (see Figure 3.9). In total 18 KSS reports out of 163 (11%) were higher than 6. Those were reported by five drivers out of 12 (41%) and 15/18 reports were during daytime. A review of KSS sensitivity as an indicator of insufficient sleep and impaired waking function show that KSS levels above 6 in general are related to increased numbers of incidents (Åkerstedt et al., 2014). The KSS results were similar to those achieved in a Swedish experimental study on bus drivers during afternoon driving in a daytime shift showing KSS 3.86 (SD 0.23) and a total of 5/18 drivers (28%) with KSS reports higher than 6 (Anund et al., 2018), but also to an explorative real road study on city bus drivers showing low levels in general, but occasionally high levels of sleepiness occurred (Ahlström et al., 2018). The latter study also highlights the importance of taking the complexity of the driving task into consideration for sleepiness detection, something that is also emphasized in other studies where results indicate that action demand is important to understand sleepiness in drivers (Ahlstrom et al., 2017). Results from GLM ANOVAs can be seen in Appendix K.

The average self-reported stress level measured with the Stockholm Stress Scale (SUS) was 3.02 (SD 0.68) during morning and 2.95 (SD 1.50) during daytime (see Figure 3.9). In total 3 SUS reports out of 163 (2%) were above 6, and those were reported by two drivers and only during the daytime drive. During daytime, there was more traffic, congestion and interaction with other road users, issues that might be expected to contribute to a higher workload.

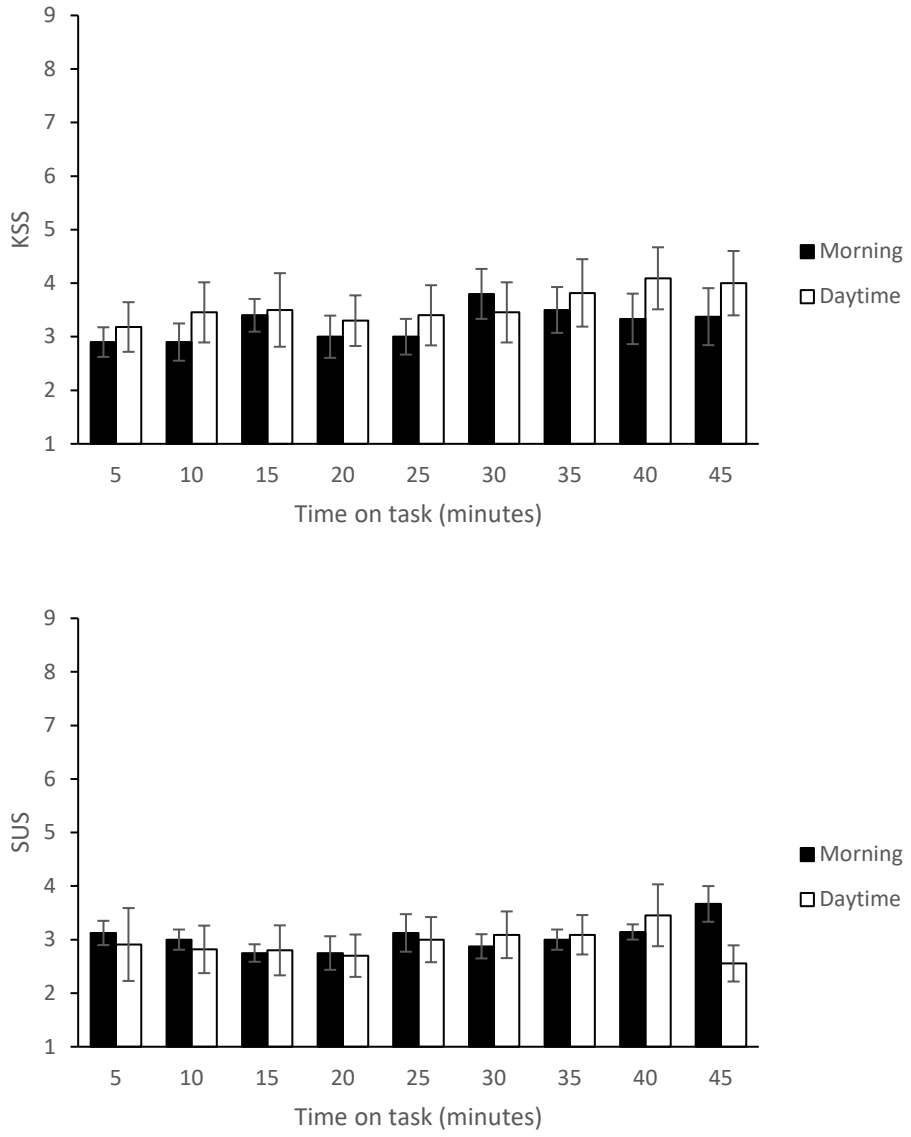


Figure 3.9 KSS and SUS morning and daytime. Error bars represent standard error of mean (SEM)

One commonly used indicator of fatigue is long blink durations. The average blink duration was significantly longer during morning drives (mean 0.134 seconds; SD 0.027) compared to daytime drives (mean 0.124 seconds; SD 0.0321) (see Figure 3.10). The same pattern was seen for the percentage of long blink durations (>0.15 seconds), with significantly higher percentages of long blinks during mornings compared to during daytime drives (see Figure 3.10). Most studies looking into the effect of long blinks on safe driving are done on rural roads and do not involve handling complex environments such as urban driving. On rural roads it has been shown that blink durations >0.15 seconds are associated with an increased risk for the vehicle crossing the lane demarcation line (Fors et al., 2011). It has also been indicated that long blink durations have a different effect on line crossings depending on whether they are prevalent during daytime or night time (expected sleep deprivation condition) (Anund et al., 2017).

Worth mentioning is that from the video analysis, one driver had problems keeping his eyes open and showed signs of falling asleep at red lights, in queues and at bus stops. The driver's report of KSS did not correspond to the view from the video, indicating a possible risk of drivers underestimating sleepiness or not understanding how to use the scale. It is not known why, but studies on bus drivers

have shown that they seem to use the self-reports in a different way compared to other populations that have been studied mostly in situations with more task-related underload. One explanation might be that the bus drivers were fully occupied with the driving task in the complex environment, which might make it difficult to give self-reports due to overload. They could also be less familiar with how self-rating scales work.

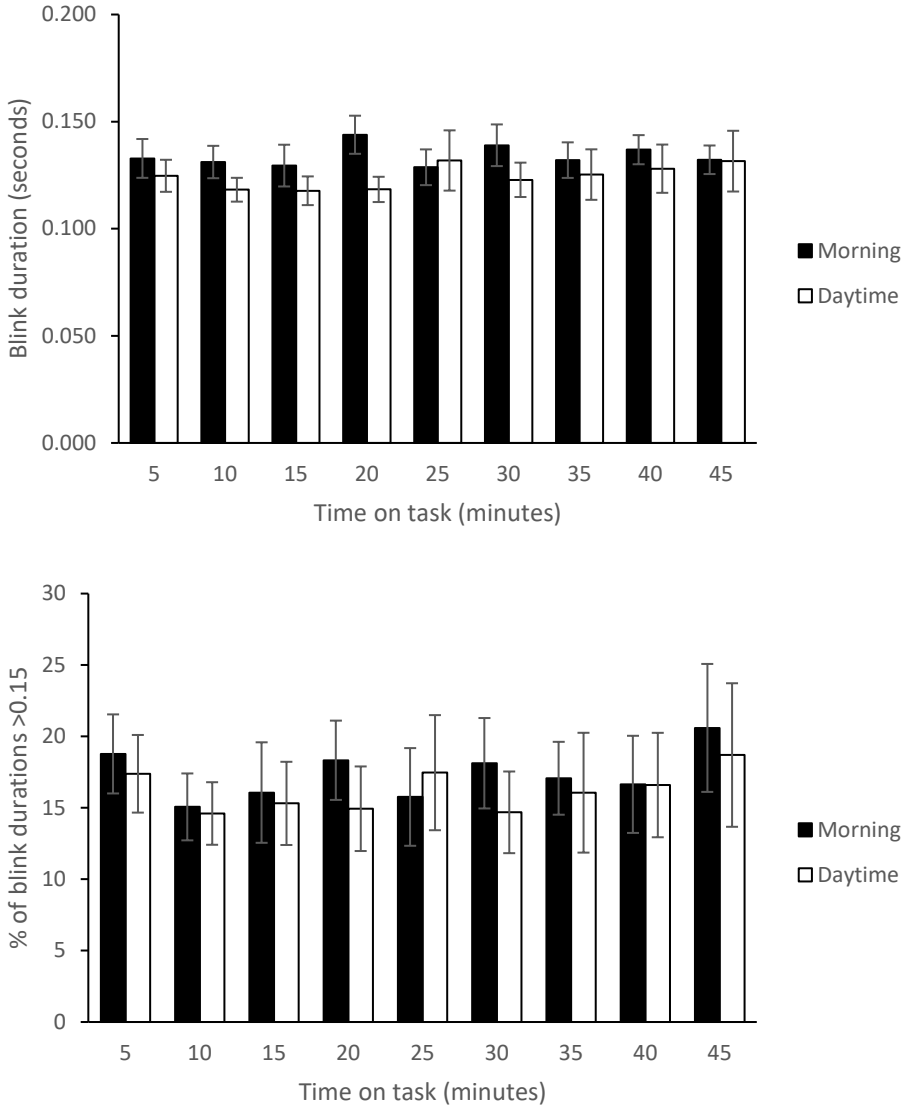


Figure 3.10 Mean blink duration and percentages of blink durations longer than 0.15 seconds. Error bars represent SEM.

There was a significant difference between heart rate variability (HRV) during mornings (mean 0.03831; SD 0.0179) compared to daytime driving (mean 0.03221; SD 0.130) indicating higher psychological stress during daytime than during morning (see Figure 3.11).

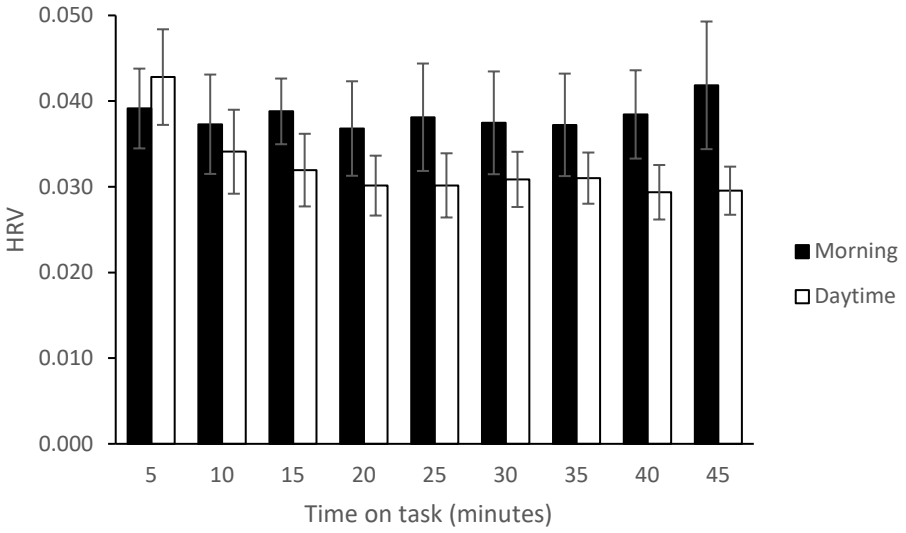
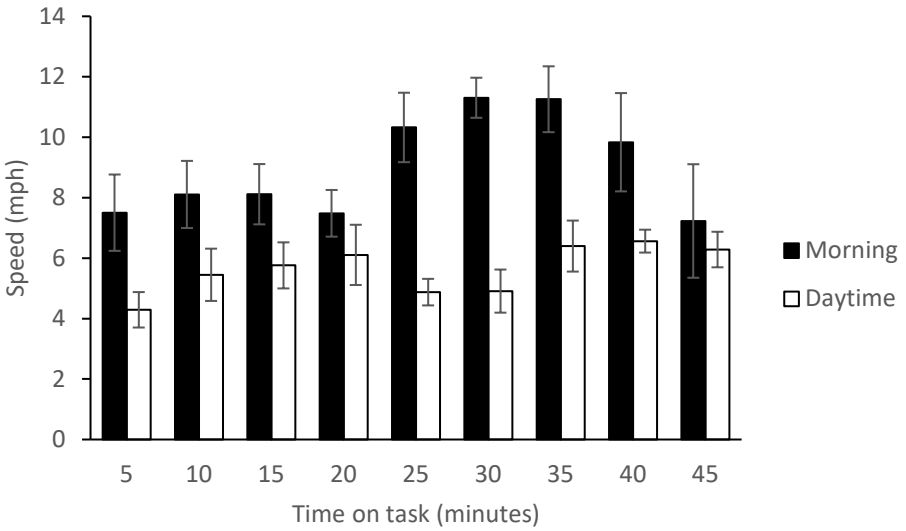


Figure 3.11 HRV RMSSD. Error bars represent standard error of mean (SEM)

Driving behaviour during morning and daytime differed significantly (see Figure 3.12). The average speed was higher during morning (mean 9.00 mph; SD 3.55) than daytime (mean 5.64 mph; SD 2.38). The same pattern was seen for accelerations and decelerations. It is not possible to determine whether these findings are caused by the effect of time of the day itself or the change in driving conditions because of time of day i.e. daytime driving being more demanding with more traffic, pedestrians and cyclists. Most likely it is dependent on the complexity of the driving task and the demand for action due to high traffic density (Ahlstrom et al., 2017). Whether or not the levels of accelerations/ decelerations will lead to risky situations is hard to say, but it would likely not be comfortable for the passengers and with higher accelerations/ decelerations there is a risk for standing passengers to fall. The impact of accelerations on whether or not passengers fall on the bus, is highly dependent on various other factors such as whether or not the passenger is standing, their position, whether a handrail is present, and whether or not they are on the stairs. However, research has shown that it is more common for passengers to experience a fall when acceleration is greater than 2.5 m/s^2 (Karekla & Tyler, 2019).



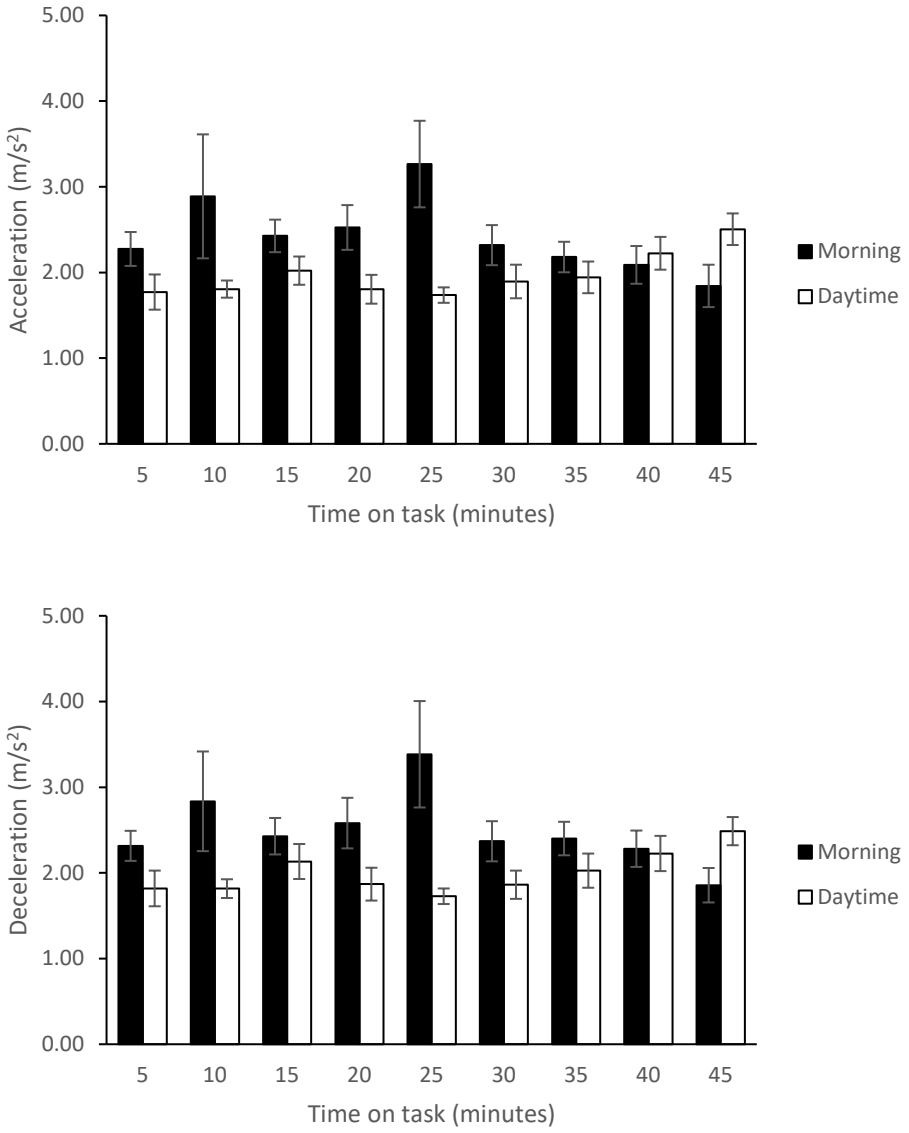


Figure 3.12 Speed, Accelerations and Decelerations. Error bars represent standard error of mean (SEM)

3.6.1.5 After drive questionnaire

It can be generally noted that many drivers indicated values in the low extreme throughout the questionnaire, i.e., stating that they experienced no stress at all. No significant difference between morning and daytime was found on any of the three variables; difficulties in staying awake, feelings of stress, and worry while driving ($p>0.05$). Thus, according to the responses in the questionnaire, the time of the day they work did not seem to influence experiences in the area of (a) difficulties in staying awake, (b) stress while driving, or (c) worry (see Figure 3.13). Although self-reported sleepiness and stress were higher during the daytime drive, these responses can not be directly compared to those in the after drive questionnaire. First, two different scales were used to assess both sleepiness and stress whilst driving and after driving. Second, the after drive questionnaire required drivers to respond retrospectively whilst the scales used during the drive involved real time reporting. Therefore, greater weight should be placed on self-reported sleepiness and stress ratings during the actual drive.

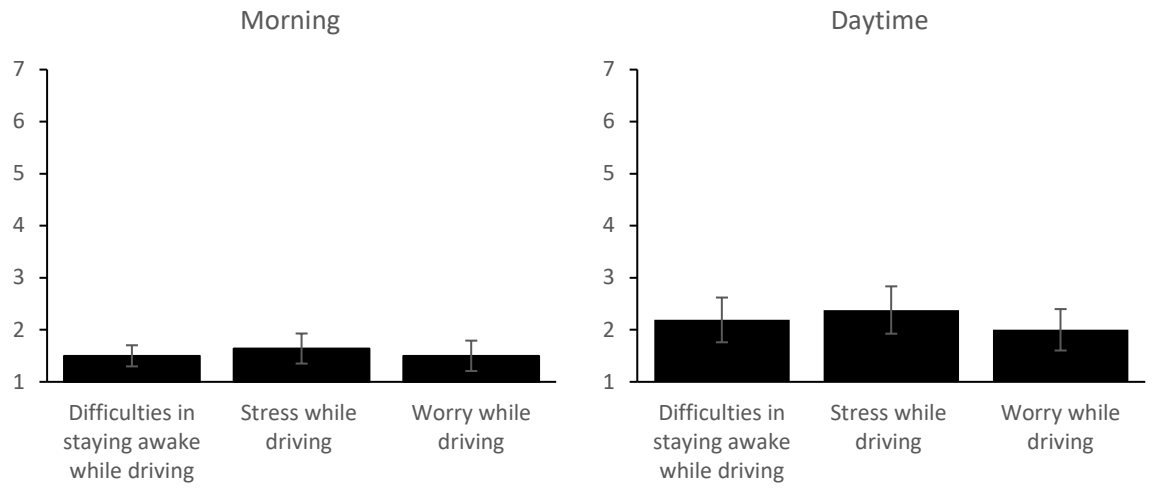
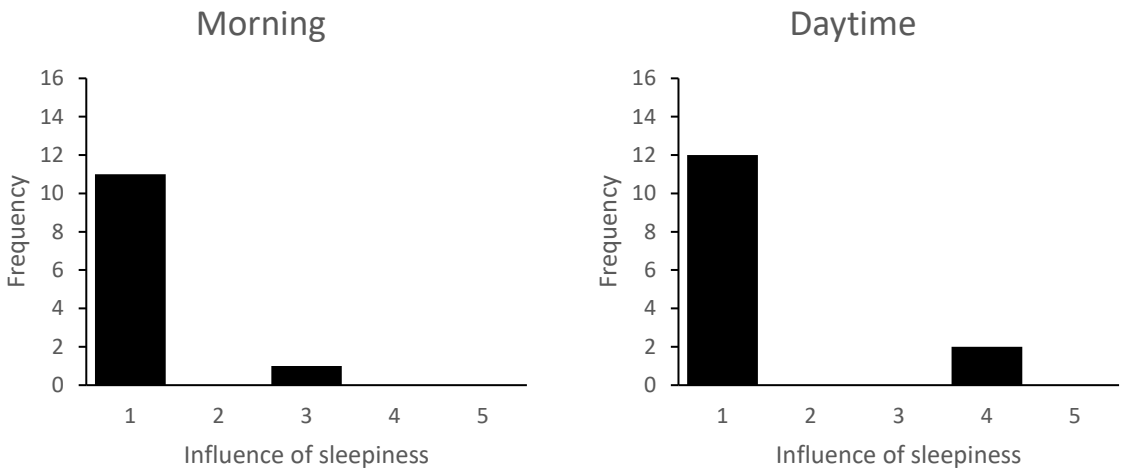


Figure 3.13 Drivers experience of sleepiness, stress and worry while driving.

The drivers considered the experimental drives in general to be fairly similar to an ordinary drive on the same route, with no major difference between morning (mean 5.6; SD 1.7) and daytime driving (mean 5.3; SD 1.9).

The drivers tended to report that sleepiness, inattentiveness or stress had no influence on their driving (see Figure 3.14). There was no significant difference between morning and daytime reporting ($p>0.05$). One driver reported losing attention during the day drive and eight drivers, five in the morning (36 %) and three in the day (19 %), reported experiencing sleepiness at some time of the drive. Four drivers, one in the morning and three in the day, reported using a countermeasure to stay awake. From the free text answers, it could be seen that these incorporated drinking energy drinks, chewing gum and singing. None of the drivers indicated that control of the vehicle was lost during the drive. In all, this is in line with what previous research has shown (Anund et al., 2008).



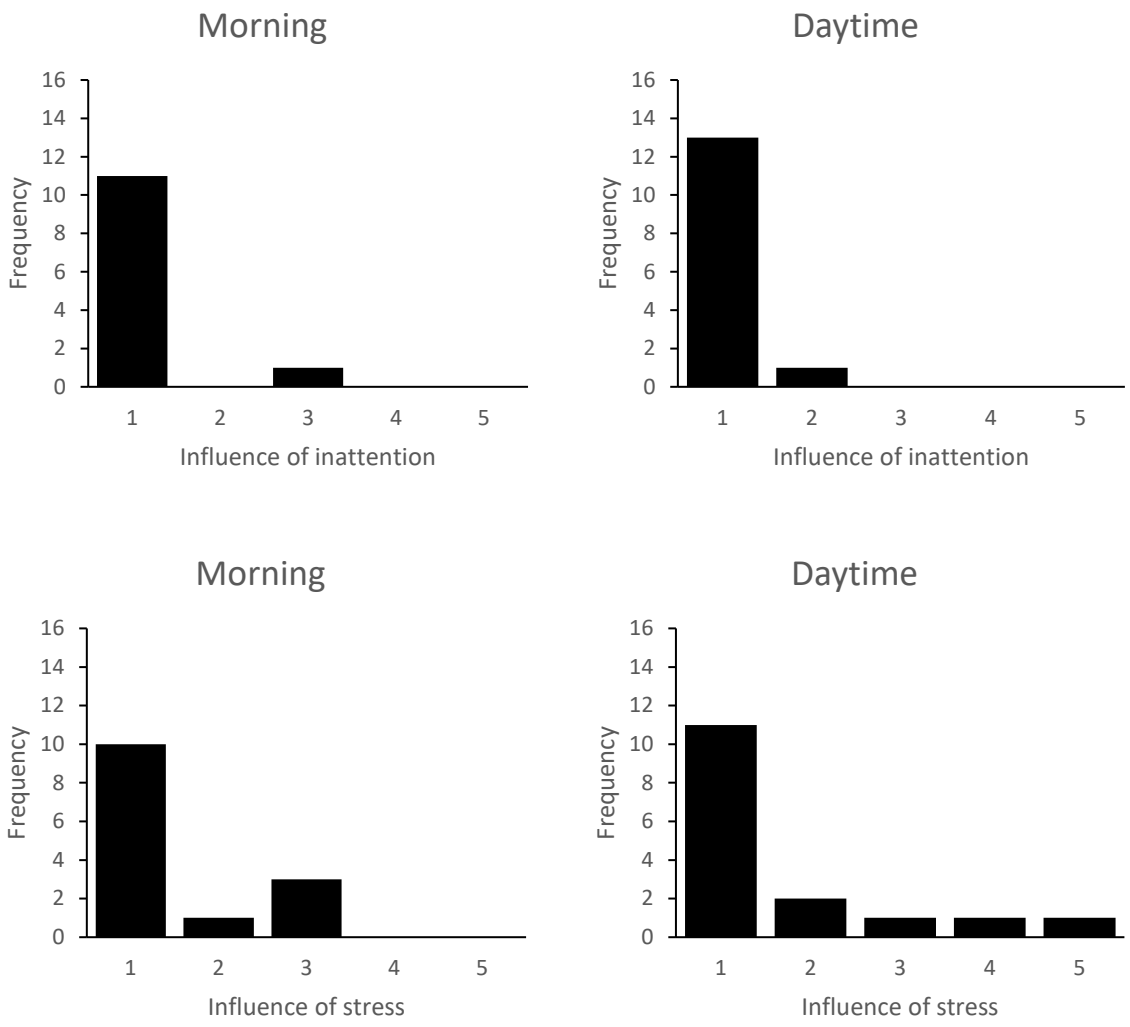


Figure 3.14 The influence from sleepiness (top), inattention (middle) and stress (bottom) while driving

Responses to the free text questions suggest that the reasons for experiencing stress, fatigue and inattentiveness were short sleep, (difficult) interactions with traffic, passengers and traffic controllers, time pressures, family matters and illness.

3.6.2 Summary

To summarise:

- Drivers sleep too little especially before morning shifts (1.5h less than recommended)
- In general, self-reporting of sleepiness is not very high, but individuals report high levels now and then.
- The drivers report higher sleepiness during daytime than during morning drives.
- However, objective measures like blink durations show more sleepiness signs during mornings.
- There is a need to be aware of fatigue as a potential risk not only at times of the day when you would like to be in bed, but also at times of the day when the task itself is demanding.

4 Discussion of potential solutions

The following section discusses the proposed solutions derived from the research that could potentially mitigate fatigue in London bus drivers. It is important to recognise that the responsibility to manage fatigue is shared. The solutions discussed are relevant for all involved parties (drivers, managers, operators at all levels, TfL, borough councils, unions, and the Department for Transport [DfT]). In order for any solution to be effective each party must take ownership of the issue and where possible provide support to facilitate all other parties in fatigue management efforts.

As part of this programme of research, operators were asked for policy documents that related to fatigue, which have been summarised in section 3.2, the internal policy review. However, it is possible that some fatigue policies were not volunteered at the time, or that policies and initiatives relating to fatigue have been implemented and adopted since the request was made. Therefore, there may be some instances where aspects of the themes and solutions are already being undertaken, for example trialling fatigue detection technology, utilising biomathematical models of fatigue in relation to scheduling, or providing adequate facilities for drivers to eat and rest. It is also important to focus on establishing a standard in terms of fatigue mitigation, that can be applied across operators and TfL.

Within this section, solutions and countermeasures are discussed which can be targeted across two levels, individual and organisational. Individual countermeasures refer to the strategies and solutions that individuals themselves can adopt and use to alleviate fatigue and sleepiness, including preventative strategies to help mitigate fatigue before it occurs, and operational strategies aimed at mitigating the effects of fatigue which may be present. Solutions can also be targeted at an organisational level, for example implementing a fatigue management system, educational programmes, or providing rest facilities. It should be noted that the proposed solutions and countermeasures to driver fatigue have not been evaluated (meaning that they have not been subject to a randomised control trial, or a comparison before and after the implementation of a certain solution). They have been proposed and their potential rated based on findings from the literature review and the research conducted as part of this body of work. It is also important to note that the scientific literature considered is limited in that no objective, high quality evaluation of solutions and countermeasures to fatigue and sleepiness in drivers, especially bus drivers, were identified. Therefore, it is recommended that if any solutions are implemented, an evaluation into the effectiveness of the countermeasure should be conducted.

Each research task (literature review, policy review, focus groups, manager interviews, online survey, and on-road study) resulted in several findings which were then consolidated, and potential fatigue countermeasures or solutions were generated (a summary of the tasks which influenced each solution can be found in Appendix L). The proposed solutions were then reviewed by the research team as part of a two-day workshop discussion, considering the strengths and weaknesses of each, and discounting those solutions with little or no potential to reduce driver fatigue. Five themes emerged from the discussions: education, working conditions, schedules, open culture, and health, with the recommended solutions fitting within these themes. These themes and respective solutions were then allocated ratings according to the potential for reducing driver fatigue, anticipated time to introduce the solution, indication of cost and the effort required to achieve the full potential to reduce driver fatigue. The ratings are provided as a guide only, as in reality, additional factors could influence the outcomes, with cost, potential for reducing fatigue, and time to introduce being dependent on the manner in which the solutions are implemented. Within each theme, there is also information detailing, where possible, the use of similar countermeasures in other, relevant, occupational and transport settings. The idea of a multi-level approach to address and manage

fatigue in occupational settings is becoming increasingly popular, with a recent consensus statement from the Working Time Society providing broad guidance on managing sleep-related fatigue associated with non-standard working hours (Wong, Popkin & Folkard, 2019). Within the current report countermeasures were discussed in section 3.1.1.3, in the current chapter examples from literature are provided where possible in discussing potential solutions. However, a systematic literature review of countermeasures to sleepiness and fatigue has not been conducted, rather the primary focus is on literature related to bus drivers and the proposed solutions.

It is important to bear in mind that the proposed solutions described below are fatigue and sleepiness focused. There may be broader operational issues that would need to be taken into account when considering if, or how, to implement these solutions.

4.1 Solutions overview

The summary table below (Table 4.1) identifies the five overall themes which emerged from the consolidation of findings and compares the ratings of the various outcome measures in relation to each other. Following this, each theme is discussed in more detail, with the proposed solutions ordered in terms of the numbers of research tasks the solution arose from.

The ratings provided should be used a guide only - knowledge of fatigue and the evaluation of fatigue countermeasures, especially in relation to bus drivers, is limited resulting in difficulties for applying ratings for each of the themes. The ratings were informed by the literature review, the research conducted, and the expertise of the researchers. As the field of fatigue and countermeasures is underdeveloped, particularly in relation to bus drivers, no objective, high quality evaluation of potential solutions and countermeasures has been conducted. Therefore, none of the proposed themes have been awarded the top rating for the potential for reducing driver fatigue. Solutions which are thought to have no potential for reducing driver fatigue have been excluded from the proposed solutions. In terms of anticipated cost, this is only an indication, as the actual costs of implementing proposed solutions have not been researched or evaluated. Cost and time may also vary depending on the approach taken or the solutions that are addressed within themes, which could be exponentially higher depending on which aspects are implemented. Introducing any mitigation or solution to fatigue will be influenced by, and require the engagement of all parties, and should be viewed as a shared responsibility by all.

Table 4.1: The 5 overall themes which emerged from the consolidation of findings, including ratings of various measures relevant to each other

	Potential for reducing driver fatigue	Anticipated time to introduce	Cost indicator	Effort required to achieve the full potential to reduce driver fatigue
Education	*	Short term	£	•••
Working conditions	***	Medium term	£££	••
Schedules and rosters	***	Short term	£££	••
Open culture	****	Long term	£-£££	•••
Health (including sleep health)	**	Medium term	££	••

All values relative indications only.

Potential for reducing driver fatigue:

********* Demonstrated to be effective by several high-quality evaluations with consistent results.
******** Demonstrated to be effective in certain situations.
*** Likely to be effective based on evidence and sources reviewed.
** Effectiveness undetermined, different methods of implementation may produce different results**.**
* Limited and restricted potential for reducing fatigue.

Anticipated time to introduce:

Long term More than one year.
Medium term More than six months but less than one year.
Short term Six months or less.
These estimates do not include the time required to enact legislation or establish policies.

Cost Indicator:

£££ Requires extensive new facilities, employees, equipment, time, or publicity, or makes heavy demands on current resources.
££ Requires some additional employee time, equipment, facilities, and/or publicity.
£ Can be implemented with current employees, possibly with training; limited equipment costs, facilities, and publicity.
These estimates do not include the cost of enacting legislation or establishing policies.

Effort required to achieve the full potential to reduce driver fatigue:

••• Requires maximum effort, with all parties involved and engaged, to achieve the full potential of reducing driver fatigue.
•• Requires some effort to achieve the full potential of reducing driver fatigue.
• Requires minimal effort to achieve the full potential of reducing driver fatigue.

Although the following sections have been separated into the five themes, with the respective solutions listed below, it should be noted that a holistic approach, which encompasses or addresses aspects of each of the themes, would potentially prove to be the most beneficial in terms of reducing driver fatigue.

Within each theme the solutions have been ordered according to the number of times they emerged from a task.

4.2 Education

	Potential for reducing driver fatigue	**Anticipated time to introduce**	**Cost indicator**	**Effort required to achieve the full potential to reduce driver fatigue**
Education	*	Short term	£	•••

4.2.1 Overview

Research indicates that educating people on aspects of sleep, shift work, and effective measures to counteract sleepiness, can be a useful and important prevention strategy. In terms of bus drivers, literature has indicated the need for education interventions in terms of sleep hygiene (Deza-Becerra et al., 2017), the importance of sleep in relation to driving (Razmpa et al., 2011) and countermeasure use, in particular during split shift working (Anund et al., 2018). It is important that other parties are also involved in education and training, such as managers and shift schedules, to ensure that the knowledge level regarding fatigue and sleepiness is similar throughout the operation. Research has shown mixed results in terms of the effectiveness of training in reducing fatigue and sleepiness amongst drivers, however changing behaviour and attitudes can take time, and it may be that in previous studies, the training has been too simplistic, or one-off training has been delivered, with limited effects.

4.2.2 Proposed solutions

- **Education relating to sleep and lifestyle**
  Education relating to sleep and lifestyle for all drivers, in particular new drivers who may not have experienced shift work before. This should include promotion and education relating to management of rest, emphasising **driver responsibility to prioritise sleep and ensure they are well rested prior to duty**. For instance, TfL have recently funded a new one-day Certificate of Professional Competence (CPC) training course, 'Destination Zero', which will be delivered to all 25,000 bus drivers over the next 18 months, which includes a focus area of fatigue and wellbeing management. However, education packages should also be extended beyond drivers and delivered to the majority of people within operators such as managers and shift schedulers, to provide an overall understanding of sleep, shift work, and effective countermeasures to sleepiness. The importance of including education as a fatigue mitigation strategy lies in the increasing of awareness of fatigue in the workplace, which will likely aid in the success of further implementations (Williamson & Friswell, 2008). Research has shown that short, one off training programmes have limited effectiveness. Following a mandatory 60 to 90 minute training session providing information and advice relating to sleep and countermeasure use, shift workers still consistently obtained less than adequate sleep (Arora, Georgitis, Woodruff, Humphrey & Meltzer, 2007). Therefore, longer programmes, for example a set number of sessions, may be more effective (Chen, Kuo &

Chueh, 2010). However, it has been reported that education as a sole fatigue countermeasure is ineffective at changing sleep behaviours (Pylkkönen et al., 2018) and therefore will most likely have limited impact if implemented in isolation.

4.2.3 Potential for reducing driver fatigue

Driving research has indicated that education strategies work well for individuals who are not already aware of the risks of fatigue (Gander et al., 2005). However, education can have a limited impact on those who understand the risks of fatigue, but continue due to other factors (Armstrong et al., 2010; McCartt et al., 2000; Nordbakke & Sagberg, 2007), with financial and business demands creating additional pressure for professional drivers (Firestone & Gander, 2010). Education packages need to be realistic and relevant, and require individuals to engage with the content, focusing on recognising the symptoms of fatigue, the causes, consequences, and countermeasures, and have the motivation to act on the knowledge that they have learnt. Of particular importance in a workplace context is that individuals need to be provided with the opportunity to implement learnt strategies, whether that be adequate rest periods between duties to ensure sufficient sleep, suitable facilities and the open culture to allow drivers to nap during breaks, or the system in place to be able to report fatigue. It is also important that training and education is conducted with fully alert participants, who are responsive and willing to engage. If training is conducted following a normal working shift, or on sleepy individuals, the learning is likely to be limited. Therefore, it is important to consider the time the training and education is delivered. The complexities of these factors are highlighted below in Figure 4.1. Although education can offer some benefit, the potential for reducing fatigue is limited.

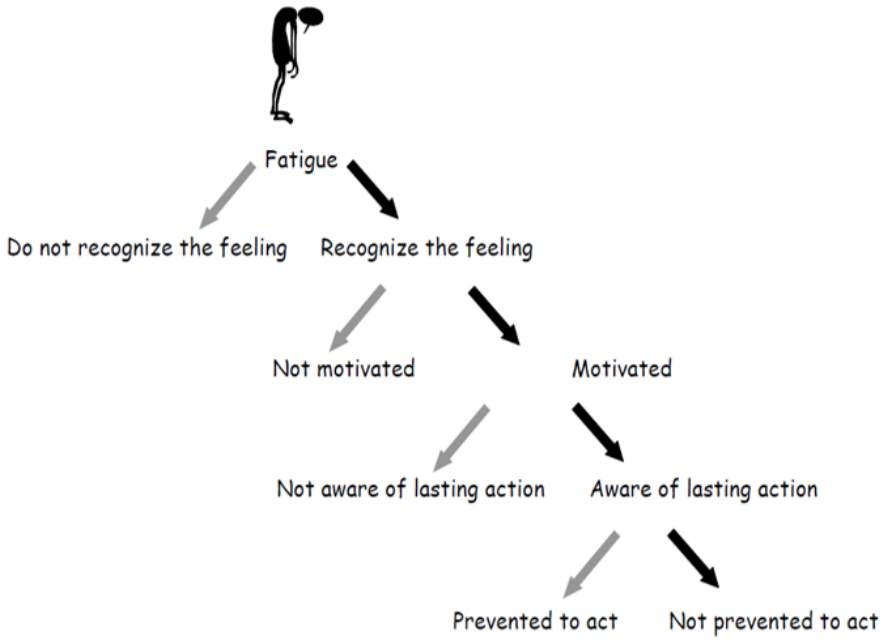


Figure 4.1: The chain of decisions relating to countermeasure use and driver fatigue (Anund, Fors, Kecklund, Leeuwen & Åkerstedt, 2015).

It is important to note that while there has been evidence to suggest that education as a sole intervention to reduce fatigue and sleepiness can be ineffective, education and training are the cornerstones of other interventions, with most other potential solutions requiring an element of training and education.

4.2.4 Anticipated time to introduce

The anticipated time to introduce would be short, as this would be an addition to the education already provided by operators, focusing only a part of their training programme on fatigue. However, this would depend on the time to develop the additional material and inform/train the current facilitators. A further consideration is the time taken to deliver the training course to the driver population, which may take considerable time, and may involve additional costs, such as covering shifts during training, which needs to be taken into account.

4.2.5 Indication of cost

The potential cost of implementing an education package relating to fatigue should be relatively low, as operators currently provide training and education to their drivers on a regular basis. Therefore, the proposed fatigue education could be incorporated into the current training package, requiring little additional cost. However, if education cannot be incorporated into current packages, then the associated cost will be higher. For example, operators currently use the CPC format of a one-day training course per annum, which includes varying content. Therefore, introducing a 'fatigue package' alongside or in addition to this may incur significant costs. Training and education solutions could incorporate operators providing in house training, or a standardised approach across all TfL routes. The quality, content and consistency of the material across TfL and operators will influence the variability of results.

4.2.6 Effort required to achieve the full potential to reduce driver fatigue

As mentioned above, while offering some benefit, especially to new drivers, education as a sole fatigue countermeasure can face several challenges. Although the time to implement is possibly short, and the indications of cost may be low, thought needs to be put into the content of the education package, and how it will be delivered to make sure that it is engaging, relevant, and realistic, all of which requires effort. However, to potentially reduce driver fatigue, individual motivation as well as responsibility for managing rest and health in terms of fitness for work is required, and therefore results may be difficult to achieve.

4.3 Working conditions

	Potential for reducing driver fatigue	**Anticipated time to introduce**	**Cost indicator**	**Effort required to achieve the full potential to reduce driver fatigue**
Working conditions	***	Medium term	£££	••

4.3.1 Overview

Working conditions are an important consideration in terms of bus driver fatigue and are often out of control of the drivers themselves. Physical and psychosocial factors have been shown to contribute to health, stress and fatigue experienced by bus drivers (Tse et al., 2006), with factors such as vehicle condition and ergonomics, shift work, and the risks of violence just some of the stressors experienced by drivers. Literature has indicated associations between cabin ergonomics and fatigue (Biggs et al., 2009), and overall bus condition and accident rate (Abdullah & Von, 2011). Heat, noise, and vibration have also been shown to impact fatigue and increase stress levels of drivers (Abdullah & Von, 2011; Biggs et al., 2009) highlighting the importance of bus condition and design. Access to adequate facilities was also highlighted in the literature, with reports of bus drivers

sleeping in inappropriate places during their break due to lack of facilities, resulting in instances of poor sleep quality (Deza-Becerra et al., 2017). Concerns relating to a lack of facilities were also identified in the driver survey and focus groups. Providing facilities which enable drivers to be able to nap and rest (including access to adequate bathroom facilities), or to socialise and eat healthily, as well as maintaining buses to a suitable working standard, could potentially address some of these challenges and offer solutions in terms of potentially reducing driver fatigue.

4.3.2 Proposed solutions

- **Provide and ensure regular evaluation of suitable facilities for drivers to eat and rest**
  Literature has indicated that access to adequate driver facilities relating to rest/napping and food/eating, is an important aspect of fatigue management, with research from the various tasks supporting the need for adequate facilities (including suitable bathroom access). By providing access to appropriate rest areas, drivers would have the opportunity to nap or rest prior to duty, during breaks, or prior to commuting home, which could potentially counteract fatigue during shifts. Research in groups of shift workers has shown the beneficial effects of napping during shifts in relation to fatigue mitigation, including engineers (Purnell, Feyer & Herbison, 2002), pilots (Rosekind et al., 1995), and air traffic controllers (Signal, Gander, Anderson & Brash, 2009). Although not as recuperative for sleepiness as napping, rest breaks do provide a respite from the job and tasks, mitigating against task related fatigue and improving safety (Tucker, 2003; Tucker, Folkard & Macdonald, 2003). Access to food and healthy eating is also difficult due to timings of shifts and locations drivers find themselves in, limiting availability and food choice, particularly at certain times of the day, however providing adequate eating facilities offers potential for reducing driver fatigue and improving overall driver health. Solutions relating to drivers' diet would be linked to education and promotion regarding the benefits of healthy eating, and **improved access to facilities to enable healthy eating**. A review of literature relating to food and shift work by Lowden, Moreno, Holmbäck, Lennernäs and Tucker (2010) led to several guidelines relating to eating whilst working shifts. A key theme in these guidelines was having a variety of food options available and avoiding low-quality foods such as those high in carbohydrates or high in sugar. It is important that a regular systematic assessment is made of the facilities, to ensure that the changes implemented remain valid, and to address any risks or further interventions that need to be addressed.
- **Maintain buses to ensure they are always kept in a suitable condition**
  Previous literature and responses during focus groups have highlighted the importance of ensuring that buses are kept in suitable working conditions and to a high technical standard, to help reduce stress experienced by drivers (Abdullah & Von, 2011; Biggs et al., 2009). Drivers need to trust the bus will operate throughout their duty, with increases in stress reported if problems and issues arise with the buses. For example, it has been recognised by TfL that there have been certain technical and software issues with the new hybrid buses, and although there is no evidence that these are safety critical issues, they can cause stress and anxiety for the drivers.

4.3.3 Potential for reducing driver fatigue

Implementing solutions related to working conditions are likely to be effective at reducing driver fatigue. Often the establishment of, or access to, facilities, as well as bus maintenance, are out of the control of the driver, which potentially could impact stress levels. It is considered that providing adequate rest facilities will assist drivers with the opportunity to nap or rest. Similarly, by providing adequate food and eating areas, drivers will have the opportunity to eat healthily. It should be noted

that an audit of current facilities was not conducted as part of this research. However, in terms of facilities, individual motivation and engagement will impact the potential for reducing fatigue, so it is therefore important to educate the drivers about using the facilities, publicise the availability of any facilities, and establish an open culture to encourage napping and healthy eating. It is also important that a regular evaluation of the facilities is conducted in order to address any additional needs. Ensuring buses are maintained to an adequate standard could reduce the stress experienced by the drivers relating to the working condition of the bus, which has the potential to reduce fatigue.

4.3.4 Anticipated time to introduce

The anticipated time to introduce and implement will likely vary depending on the current facilities and condition of buses, and how these will be improved and utilised in the future. It is likely to involve a medium time scale, however, certain aspects may require considerable re-engineering of work practices and facilities to make any meaningful impact. There is also the issue of planning and set up time prior to implementation, and other features such as maintenance necessitating an ongoing strategy.

4.3.5 Indication of cost

The potential cost of implementing solutions relating to working conditions is quite high. Costs would vary depending on whether improvements to existing facilities could be made, or if new facilities for rest/napping and access to food would be needed, with additional costs relating to ongoing maintenance of buses to ensure adequate working condition.

4.3.6 Effort required to achieve the full potential to reduce driver fatigue

The effort required to achieve the full potential to reduce driver fatigue will be influenced by how the proposed solutions are addressed. Existing facilities can be improved, or new facilities created, for both rest and eating, however effort may be required to ensure that these are used appropriately, and driver input would be an important factor in terms of requirements. Although there is a shared responsibility in terms of solutions to reduce driver fatigue, there is an expectation that drivers take responsibility and manage their overall health and fitness for work, especially if the education and facilities are provided. Regular evaluation of the validity of implemented changes should also be conducted, identifying any further risks or needs. If drivers are not educated in the benefits of napping or eating healthily, and there is no engagement or motivation from the drivers or other parties, all of which requires effort, then the potential for reducing driver fatigue may be limited. For example, if drivers feel that they will be judged or penalised by their employer for using nap or rest facilities then uptake is likely to be low.

4.4 Schedules and rosters

	Potential for reducing driver fatigue	**Anticipated time to introduce**	**Cost indicator**	**Effort required to achieve the full potential to reduce driver fatigue**
Schedules and rosters	***	Short term	£££	••

4.4.1 Overview

Shift patterns and rosters directly impact drivers and their ability to rest, sleep, and achieve a good work/life balance. Literature has shown that increased sleepiness and crash risk are impacted by

long working hours (Robb et al., 2008), especially when combined with sleep loss and lack of breaks (Pylkkönen et al., 2015). Schedules should be reflective of the 'real world', for example in relation to traffic levels, with research highlighting the main contributing factor to bus driver fatigue to be unrealistic scheduling (Biggs et al., 2006). In terms of implementation, education may be required for schedule planners in order to incorporate fatigue mitigation strategies into the schedules and rosters, such as the solutions listed below. Implementing strategies that consider working patterns, rest and break times, length of duty, variability and flexibility of shifts, consecutive long or early shifts and cumulative fatigue risk is important, ensuring drivers have the opportunity to adequately manage their work and home life.

4.4.2 Proposed solutions

- **Including fatigue risk assessment and mitigation in scheduling and rostering**
  Several potential solutions relating to fatigue risk assessment and mitigation in rostering and scheduling arose from the literature, expertise, and the research conducted, and have therefore been grouped together. **Safety and fatigue should be a main consideration** when designing schedules and shift patterns, whether that be through modelling rosters through specialist software (e.g. the Health and Safety Executive [HSE] Fatigue Risk Index), limiting the number of consecutive early shifts, the number of continuous hours worked, or establishing tighter control regarding shift swapping and overtime. Understandably, scheduling and rostering for bus drivers can be complicated due to the complexity of operations, and varying staffing needs, not only daily, but sometimes hourly. This fine detail results in start times for current shift patterns varying daily. However, drivers are unlikely to adjust their bed time in such fine detail which will result in daily difference in sleep duration. **Reducing the variability in start times** within specific shifts, for example, for having all early morning shifts starting within the same small consistent time window. This will aid drivers in the planning and management of rest and sleep prior to and following duty.

  Literature has shown that in terms of shift work rotations, **forward rotating shift patterns**, which involves duty start times getting progressively later such as moving from earlies, to middles then to lates, coincide with our circadian rhythms, and are therefore easier to sleep around. It also prevents short rest periods between duties, as forward shift rotation makes it impossible to have less than 11 hours rest between shifts. In terms of rest between shifts, research has recommended that to promote optimal health in adults between the ages of 18-60, 7 hours of sleep or more per night should be obtained on a regular basis (Watson et al., 2015). Therefore, **allowing at least 11 hours rest** would ensure time for drivers to commute to and from work, rest and prepare for duty, as well as allowing opportunity for family/social time. Ensuring that shift patterns follow this rule will aid drivers in managing their rest prior to duty. Research has also shown the importance of regular and adequate breaks during duties, to enable drivers to rest, eat, and use facilities. It was noted from the survey data that drivers experience insufficient time to eat and rest, and therefore **increasing the number of breaks per duty**, especially with long duty days, may improve this and potentially reduce fatigue and stress levels. Regular rest breaks have been recommended in order to prevent the accumulation of accident risk, (Tucker et al., 2003), particularly in sustained activities such as driving. Research has shown that during an 11-hour shift, taking breaks reduced the odds of a crash by 68%, 83% and 85% for one, two or three rest breaks respectively, compared to drivers who did not take a rest break (Chen & Xie, 2014).

From the research conducted, there was a concern regarding reduced sleep prior to early morning shifts, which could potentially affect alertness, performance and safety. Sleepiness may then accumulate over the consecutive early shifts, increasing fatigue risk, as individuals may struggle to obtain adequate sleep prior to duty. Previous research has shown links between starting work too early in the morning, and short sleep duration and increased sleepiness (Ingre, Kecklund, Åkerstedt & Kecklund, 2004) partly due to the inability to go to sleep earlier to compensate. Therefore, limiting rosters to **avoid more than three consecutive early morning shifts** would mitigate this risk and potentially reduce fatigue experienced by bus drivers. However, it is understood that introducing rules such as this may not always be feasible from a business point of view. One policy which has been adopted by some operators is to use shorter shift lengths for early shifts in an effort to mitigate the associated fatigue effects with consecutive early starts. Due to the findings in the literature review, it was expected that spread-over shifts would emerge as a major issue for bus driver fatigue, however, from the research conducted, split shift working does not often occur in London, which is positive. Moving forward, this approach should be continued, **avoiding the use of spread-overs** to help mitigate fatigue risk.

There are currently **biomathematical models** which have been established to predict the impact of shift schedules on respective sleep, alertness, and performance (e.g. the HSE Fatigue Risk Index). This or other similar tools could be useful when designing shift schedules or making changes to current roster patterns. However, biomathematical models do have several limitations, such as only considering potential fatigue, and generally requiring some background knowledge or understanding of fatigue and sleepiness in order to adequately interpret results. Importantly the person implementing the model should be fully trained in its use and interpretation. The models should not be used in isolation, but within a comprehensive fatigue management system. The majority of models have been validated or used within shift work populations, therefore there would be applicability for use within this industry, however to date, there is limited evaluated use of biomathematical models specifically to bus drivers. The use of bio-mathematical models of fatigue have grown in popularity, with reported use in several transport industries. Within aviation, work has been conducted comparing various commercially available biomathematical models for use within a comprehensive fatigue risk management system (Civil Aviation Safety Authority, 2014), and it is thought that within the UK rail industry, the most widely used fatigue model is the HSE FRI (Bowler and Gibbon, 2015).

- **Protecting break and rest times**
  Research has indicated the importance of rest and break time during and between duties, to ensure that drivers are alert and adequately rested. It has been shown that time on shift increases the risk of a fatigue related incident (Folkard & Lombardi, 2006; Hänecke, Tiedemann, Nachreiner & Grzech-Šukalo, 1998; Nachreiner, Akkermann & Hänecke, 2000; Wagstaff & Lie, 2011), and adequate rest breaks are a crucial element of fatigue mitigation. Drivers are allocated a break during their shift, e.g. for lunch, which usually approximately 1 hour. In addition, there is 'recovery time' at the end of each route, built into the schedule with the aim of accounting for delays. Regardless of the length of lunch break offered by an operator, 40 minutes of this time is protected (which is 10 minutes more than the GB domestic drivers' hours require). Data from focus groups, manager interviews, and the online survey highlighted that the recovery time can sometimes be infringed upon, impacted by situations such as late running times. However, from the research conducted, it was clear that the infringement on the recovery time was perceived by the drivers as an infringement

on their break time. This difference between what is defined as a break versus what is defined as recovery time and perceived breaks should be addressed to avoid confusion and to help drivers plan and manage their breaks, rest, and the use of any individual countermeasures to fatigue. Providing adequate breaks and rest could allow for napping and healthy eating and reduce stress for drivers. In terms of rest between duties, there should be protection surrounding time for drivers to commute to and from work, sleep and rest, eat, and have adequate family time, which should also ensure drivers are sufficiently rested and reduce their stress and improve their well-being.

- **Ensure that schedules are better matched with actual running time, at all times of day**
  Linked to protecting break and rest times, increasing the running times during peak hours was a solution raised from the focus groups, survey and literature review. It was reported that during these peak periods, it can be difficult to complete routes in the allocated time due to pressures e.g. volume of traffic, with added factors such as roadworks and congestion, a common occurrence in city centre driving. Schedules should be reflective of the 'real world' and introducing dynamic scheduling, for example allowing additional running time during busy periods so drivers are not rushing, and likewise reviewing schedules to make sure time is used efficiently, would help to reduce driver stress, and ensure turnaround times are manageable. Consequently, the relationship between drivers and traffic controllers may also be improved. Although the focus of the solutions is fatigue, it is recognised that when considering mitigation strategies, there are other business factors which also need to be balanced.
- **Providing more flexibility regarding drivers' shifts**
  Data from the focus groups and manager interviews highlighted the desire for greater flexibility regarding shifts, although this would need to be considered in terms of safety and fatigue. **Considering the chronotype of the driver** when designing rosters may also be a fatigue mitigation strategy, for example, allocating a fixed roster to match a person's chronotype. The chronotype of an individual, that is, whether they are a morning type or an evening type, is related to their underlying circadian rhythms and preference for sleep during a 24-hour period. For example, a morning type may prefer to go to bed early and get up early, and feel alert in the morning, whereas an evening type may prefer to go to bed later and wake later and feel more alert in the evening. In terms of shift work, morning types may find it easier to obtain adequate sleep prior to early morning shifts, whereas an evening type may struggle. However, it may also be that drivers prefer rotating shifts, and that they are able to manage their rest well around them. If drivers are able to select their own hours or shift preference, individual motivation may need to be considered, as a driver may look to try to maximise their time off by condensing their work time, or may choose shifts based on their social and/or family life, both of which may increase fatigue risk. It is positive to allow some degree of flexibility, however there should be some limitations, and consideration would need to be given to how this is achieved. Furthermore, it should be acknowledged that there is a balance to be struck between flexibility and running an efficient operation, so although some flexibility may be allowed there will necessarily be a limit (due to the time required competing with the other duties managers have) to how flexible operators can be.

4.4.3 Potential for reducing driver fatigue

Implementing changes to schedules and rosters is likely to be effective at reducing driver fatigue. Similar to the establishment of, and access to, facilities, schedule and roster design is often out of the control of the driver, which could potentially impact stress levels. Several of the proposed schedule and rostering solutions would have a direct effect on driver fatigue, for example enabling

drivers to plan and manage their rest both during and between duties. However, changes need to be considered with safety in mind, and education may be required to encourage engagement with any proposed changes, and to ensure drivers know how to effectively manage their rest and are motivated to do so. Making fundamental changes to rosters may also have several limitations from a driver point of view. Introducing certain rostering practices such as limiting the number of consecutive earlies, may have a significant impact of the working life of the bus drivers, for example reducing the flexibility in their rosters, and potentially limiting their financial options by restricting overtime allowances. Therefore, certain proposed changes could be met with resistance, with the need for balance between fatigue mitigation, operational need, and driver satisfaction.

4.4.4 Anticipated time to introduce

The anticipated time to implement solutions relating to schedules should be relatively short term, as the techniques and resources are already in place to design schedules. However, this would depend on the time to review the potential solutions before they can be implemented and whether additional resources are needed. It may also be that changes require the agreement of several parties, which may take additional time to discuss, negotiate, and agree.

4.4.5 Indication of cost

Implementing solutions relating to schedules and rosters would require some additional operator and employee time, and possibly additional training. It would also depend on the level at which each of the solutions is addressed, as several of the solutions may impact operations and require additional employees or buses, and therefore the costs may vary. If changes require considerable re-engineering of work practices and pay structures to make any meaningful impact, then both time and cost may increase significantly. In the first instance, time to introduce new rosters and/or schedules may be short, however any fundamental changes would most have significant cost and resourcing implications.

4.4.6 Effort required to achieve the full potential to reduce driver fatigue

Reasonable effort would be required to achieve the full potential of reducing driver fatigue. Although the majority of resources may already be in place to begin implementing solutions relating to scheduling and rostering, any changes need to be considered in terms of safety, exploring the impact of and any limitations to, the proposed solutions. If solutions are not considered, there is a chance any changes may have a detrimental effect, possibly increasing fatigue resulting in driver reluctance to engage with future fatigue mitigation strategies.

4.5 Open culture

	Potential for reducing driver fatigue	**Anticipated time to introduce**	**Cost indicator**	**Effort required to achieve the full potential to reduce driver fatigue**
Open culture	****	**Long term**	**£-£££**	●●●

4.5.1 Overview

It is important that when managing fatigue and sleepiness and attempting to mitigate fatigue risk, individuals feel supported, moving away from the notion of a discipline-based culture. Therefore, it is important to establish an open culture in terms of fatigue. It is likely that everyone will experience aspects of fatigue at some point, whether through scheduling, poor sleep, or family/social

circumstances, so it is important that a system is in place to manage this and offer support to the individual. Recently there has been a move toward establishing evidence-based safety cultures, (Lerman et al., 2012) emphasising data driven continuous learning, with a positive safety culture supported by management commitment. However, to implement an effective fatigue system, open culture needs to be established, encouraging reporting and engagement with changes and initiatives. Input, cooperation, and open discussions from various stakeholders (e.g. employers, workers, occupational health and safety professionals and policy makers), are vital components of establishing an effective fatigue management system (Wong et al., 2019). In terms of many of the proposed solutions related to open culture, it is suggested that TfL and operators discuss these with other companies that have achieved an open culture, or started to implement elements of this, this will allow them to gain first hand advice that is unlikely to be covered within the scientific literature.

4.5.2 Proposed solutions

- **Fatigue risk management**
  In recent years, emphasis has been placed on fatigue risk management (FRM), with the encouragement of evidence-based safety management systems, risk assessments, and mitigation strategies tailored to specific company policy, all supported by management commitment to a positive safety culture (Lerman et al., 2012). Fatigue risk management systems (FRMS) are beneficial as they allow for the flexible management of fatigue, moving away from more prescribed operational approaches (Gander et al., 2011). The main consideration with FRM should be the assessment and mitigation of fatigue risk, although the systems to achieve this can vary. However, there is the potential for FRM to be abused, or become a tick box exercise with no oversight, both of which should be avoided. Data from the policy review, focus groups, and manager interviews highlighted the need for an established fatigue management system, incorporating reporting, monitoring, and mitigating of fatigue risk. A full FRMS should include clear policy's for reducing the chance of fatigue, processes for managing and reporting it if fatigue occurs, and follow up evaluation of any fatigue occurrence to inform future improvements of the FRMS.
- **Moving away from a system which is only designed to deal with discipline**
  For an open culture to be successful, there should be a move away from a discipline-based culture, to encourage individuals to engage with their employer and feel supported when reporting, discussing and contributing to fatigue related processes. For example, data from the focus groups and manager interviews highlighted that drivers may be hesitant to report or discuss fatigue events to the same person who has responsibility for discipline related proceedings. Several research tasks have also highlighted the importance of establishing a system to monitor fatigue incidents, with the **ability to report a near miss due to fatigue**. However, before fatigue reporting is encouraged, it is important that drivers have the ability to, and the motivation to, report near misses in general. This encouragement will come from establishing an open culture and moving away from a discipline-based system, with research indicating that perceptions held by employees of management safety practices within the trucking industry were predictive of fatigue reporting and near miss reporting (Morrow & Crum, 2004). Monitoring fatigue is necessary in terms of informing changes to policies or procedures, to identify issues relating to fatigue, and reviewing and evaluating any fatigue mitigation strategies. By establishing an open culture surrounding fatigue reporting, drivers should be encouraged to report related incidents so that they can be reviewed, and any support can be offered in terms of managing fatigue in the future. Moving away from a discipline-based system will take extensive time and involve commitment from all parties.

Relationships and trust will need to be developed in order to encourage reporting without fear of disciplinary action.

- **Improving the relationship between drivers, managers, and traffic controllers**
  Focus groups, and manager interviews indicated tension and stress surrounding relationships between the drivers, managers, and traffic controllers, which potentially could impact fatigue levels. It is important to understand the cause of this tension, and look for ways to improve the relationships, to help reduce driver stress and fatigue levels.
- **Openness to new technology**
  In recent years there have been developments in the use of technology to detect and monitor fatigue states. There are numerous systems available which have been briefly covered in section 3.1.1.3.3 (see Dawson et al., 2014 for a review on fatigue monitoring technologies across various driving domains), however, an extensive review of fatigue countermeasure technology has not been conducted as part of this research. Many of the fatigue systems have not been independently evaluated, and therefore the suitability in relation to reducing fatigue in bus drivers is unknown. It is possible that the current systems are not sophisticated enough to detect and monitor fatigue (Dawson et al., 2014), however, with technological advancements, this may become increasingly possible. Nevertheless, it is important to stay open to new and emerging technologies, although several considerations should be made when choosing/implementing fatigue technology, including validity, reliability, generalizability and predictability (Dinges, Mallis, Maislin & Powell, 1998; Kerick, Metcalfe, Feng, Ries & McDowell, 2013). If people do not engage with new technology, it becomes difficult for suitable systems to be developed. Furthermore, it is important that these systems are used in an open culture and are not used in relation to discipline and discipline monitoring activities. It should be noted that the available technology would not prevent a fatigue event from occurring, but rather alert the driver when they have experienced a fatigue event. This therefore may prevent an accident, however, would not prevent the fatigue event itself, which highlights the importance of establishing an open culture to be able to use the technology as a preventative strategy.
- **The formation of a fatigue working group, including input from drivers**
  Research indicates that effective fatigue management includes views and inputs from all individuals, with focus group data suggesting that drivers sometimes feel omitted from these discussions. The establishment of a fatigue working group that includes representatives from the bus drivers and additional stakeholders, such as union representatives, will encourage an open culture relating to fatigue. The development of this group would provide drivers with the opportunity to express their views and be included in the decision-making process, as well as provide operators and TfL the opportunity to hear how fatigue and relevant policies directly effects the drivers, and any issues there may be. This could also be an opportunity to involve drivers in the development of new schedules or working time arrangements, or participation in the implementation of new shift systems. It is proposed that successful working groups or fatigue steering groups include balanced representation from all parties, including the company and employees (Gander et al., 2011).

4.5.3 Potential for reducing driver fatigue

Although this solution has not been formally evaluated, establishing an open culture has the potential to be effective at reducing driver fatigue. Previous research has shown that workers who feel that their company has an open safety culture are less likely to experience fatigue, engage in

fatigue-related driving behaviour, and encounter near misses when driving as part of their work (Morrow & Crum, 2004; Strahan, Watson & Lennonb, 2008). Developing an open culture is linked to many proposed solutions, and has the potential to encourage reporting, discussions relating to fatigue, sleep and health, and an openness to new systems, policies and procedures. Individuals should feel supported in aspects relating to fatigue, with the emphasis shifting away from a discipline-based system. Fatigue risk should therefore be mitigated by drivers being able to openly discuss fatigue and any issues they face without fear of negative consequences, and should engage with other aspects of the system, enabling operators to monitor incidents, and introduce additional proposed solutions. However, if individuals do not engage with the process, then it may be difficult to achieve results.

4.5.4 Anticipated time to introduce

The anticipated time to introduce and implement potential solutions relating to open culture is most likely lengthy, due to the on-going and progressive nature of the overall theme. Although introducing the notion of an open culture within London bus drivers may be relatively short term, an effective open culture should be constantly developing and improving and will require engagement from all parties involved.

4.5.5 Indication of cost

The potential cost of implementing solutions related to open culture ranges depending on how the solutions are addressed. For example, encouraging engagement with an open culture, establishing fatigue working groups, and moving away from discipline-based cultures may have minimal cost, however future advancements and implementation of technology may require substantial cost.

4.5.6 Effort required to achieve the full potential to reduce driver fatigue

In order to implement an effective open culture, maximum effort will be required to achieve the full potential of reducing driver fatigue. All parties will need to be involved and engaged with the process, encouraging a positive and open safety culture and fatigue risk management system. Establishing an effective open culture will take time and will be an ongoing process. Effort will be required throughout to encourage engagement, and to ensure that the system is continually developing and incorporating learnings. Therefore, results may take time and benefit may be difficult to achieve without full commitment to change and individuals embracing the ongoing nature of the system.

4.6 Health (including sleep health)

	Potential for reducing driver fatigue	**Anticipated time to introduce**	**Cost indicator**	**Effort required to achieve the full potential to reduce driver fatigue**
Health (including sleep health)	**	Medium term	££	••

4.6.1 Overview

Overall health and well-being of workers, including aspects of sleep health, are important elements of shift work, and can impact job performance, sleep, and safety. Research with bus drivers has shown correlations between BMI and sleepiness (Santos et al., 2013), and that factors such as poor

sleep quality, insomnia and high obstructive sleep apnoea (OSA) risk are associated with excessive daytime sleepiness (Kim et al., 2017). Implementing strategies to encourage and support improvements in health therefore have the potential to mitigate against fatigue.

4.6.2 Proposed solutions

- **Reducing stress and workload pressure whilst driving the bus**
  Findings from the literature and from the research conducted in this body of work indicated that stress is a major part of the job of a bus driver, occurs frequently, and is a risk factor for fighting sleepiness. Implementing solutions aimed at reducing stress, particularly on-road, could potentially have a large impact on drivers and potentially lead to reductions in fatigue. Solutions to reduce stress would be linked to education, working conditions, and scheduling.
- **Improving the general health of drivers**
  From the research conducted, the driver survey data indicated that the general health of bus drivers was a risk factor for fighting sleepiness. Therefore, general health promotion at the operator level and implementing solutions to improve health, possibly through facilities, education, awareness, and opportunity and access, could lead to potential reductions in fatigue. Examples may include free step counters for drivers, promotion and support for online training in aspects of sleep and health, or encouraging exercise, possibly through the organisation of group events. A literature review examining health promotion amongst truck drivers has shown that interventions lead to positive outcomes (Ng, Yousuf, Bigelow & Van Eerd, 2015), whilst a randomised control trial involving pilots found that those using a mobile application which aimed to improve general health had less self-reported fatigue than those in a control condition (van Drongelen et al. 2014).
- **Providing health screening**
  Research has suggested health screening targeted as those at most risk of fatigue, such as those with OSA and other sleep disorders (Hakkanen & Summala, 2000), would enable individuals to receive the support needed to address and manage any resulting issues. In the case of OSA, treatment outcomes are often positive with adherence to the treatment regime (Belenky, Wu & Jackson, 2011), with evidence of reductions in motor vehicle accidents following treatment of OSA (Mazza et al., 2006), highlighting the effectiveness and importance of diagnosis and treatment. Health screening could be part of a regular company check, or a one-off site visit.
- **Training for medical practitioners**
  Linked to health screening, training medical practitioners in elements such as the signs of excessive daytime sleepiness, risk factors for OSA, and appreciation of driver safety can ultimately benefit individual drivers and help to improve health and well-being. In providing training for medical practitioners whom drivers interact with, they will be better able to identify the signs of excessive sleepiness and provide suitable advice to mitigate this. For example, this could be achieved by operators contracting medical screening, or by TfL providing provision and/or information about driving days for doctors. The majority of operators currently contract out health screening to private providers, therefore it should be reactively straightforward to ensure that these providers have fatigue and shift work expertise. However, many drivers may also visit their GP for fitness certificates, or just for health checks, and increasing GP understanding of fatigue is more difficult to influence.
- **Tracking sleep health**
  Implementing systems which allow for the tracking and monitoring of overall sleep health was a solution generated from the manager interviews and the on-road study. There are various means of achieving this, from technological monitors (e.g. Actiwatches or

Readibands) to asking drivers about their sleep, with the important factor being the establishment of system or process in which general sleep is discussed, and sleep issues can be reported. However, before implementing an initiative aimed at tracking sleep health, and to increase driver engagement, an open culture needs to be established, which has moved away from a system based around discipline. By generating an open culture, individuals should hopefully feel supported enough to report sleep issues and have regular discussions relating to sleep health.

4.6.3 Potential for reducing driver fatigue

Implementing solutions to help improve the health of bus drivers could offer potential for reducing driver fatigue, however, the effectiveness may be dependent on several factors, with different methods and strategies producing different results. Educating drivers on the benefits of health and associated risk factors, providing facilities to support health improvements, as well as establishing an open culture enabling drivers to feel comfortable reporting and discussing fatigue and health issues possibly are important steps to reducing driver fatigue. However, like education, changes to health, and engagement with health strategies requires individual motivation, and therefore results may be difficult to achieve. If drivers decide to engage with implemented practices aimed at addressing overall health, then the potential to reduction in driver fatigue will be minimal.

4.6.4 Anticipated time to introduce

The anticipated time to introduce will depend on how the area of health is addressed but will most likely be medium term. It will depend on the time taken to develop strategies to address the proposed solutions and how quickly these can be implemented or organised.

4.6.5 Indication of cost

The cost of addressing health to potentially mitigate fatigue would require additional operator and employee time, and potentially additional facilities, equipment, training, and publicity. It would also depend on what level each of the solutions are addressed, and therefore the costs may vary.

4.6.6 Effort required to achieve the full potential to reduce driver fatigue

The effort required to achieve the full potential to reduce driver fatigue is again dependent on the solutions that are implemented. Supporting drivers and encouraging engagement with new policies relating to health and well-being, eating, stress, and screening would take effort in order to be effective, however again requires motivation from individual drivers to achieve possible results. There is also a shared responsibility component in order to potentially achieve a reduction in driver fatigue, with operators and TfL reviewing and implementing potential health solutions, and drivers taking responsibility for their health and utilising facilities and educational strategies to ensure they are fit for work.

4.7 Conclusion

This section aimed to discuss the proposed solutions to potentially reduce fatigue in London bus drivers. Five themes emerged from the research, (education, working conditions, schedules, open culture, and health) with respective solutions fitting within these themes. The proposed solutions were informed from the literature review and the five research tasks conducted as part of this body of work, and only those solutions with potential for reducing driver fatigue have been included in the report. Several of the solutions and overall themes overlap or complement each other, supporting the notion of a holistic approach, encompassing or addressing aspects of each of the themes, to provide the most benefit in terms of reducing fatigue.

It should once again be noted that none of the proposed solutions have been formally evaluated. Therefore, if any of the solutions are implemented, it is strongly recommended that an evaluation into the effectiveness of the countermeasure is conducted. This would require a monitoring system, and an open culture to establish engagement with the process. Reducing fatigue is also a long-term commitment with no quick fix; solutions need to be implemented in a step-by-step approach with small changes to be accepted by drivers before a more sophisticated solution is implemented over time. It is important that parties do not give up too early, especially as in the first instance there may be some resistance to change.

Although the themes were not ordered in terms of importance, it is clear that establishing an effective open culture underpins many of the proposed solutions. Strategies such as establishing a reporting system to monitor fatigue or creating rest facilities for napping will not be effective if there is no overarching open culture, where individuals feel supported in discussing fatigue and implementing strategies related to health and well-being. It is important to note that all parties (drivers, managers, operators at all levels, TfL, borough councils, unions, and the Department for Transport [DfT]) are involved in all aspects of fatigue management and that everyone has a part to play. However, this does add to the complexity of implementing potential solutions. In relation to fatigue and fatigue mitigation, everyone has a responsibility, and for the full potential to be reached of reducing driver fatigue, commitment to the process and engagement with the system needs to be achieved by all.

5 Limitations and future research requirements

5.1 Limitations

As with all research the findings should be considered in context of the limitations. One limitation of the current research related to the participants and sample size. Although drivers from all 10 operators were involved to some extent throughout the research project, the representativeness of the sample differed between tasks. In the focus groups one group of drivers which were not widely investigated were night drivers. Although some night drivers participated in the focus groups, in most cases night drivers only work nights, and would therefore have been unavailable to take part in our discussion groups as these occurred during the day.

With regard to the survey, although a final responding number of 1,353 is fairly large, this is from a total population of roughly 25,000 London bus drivers. There is a possibility that those who responded to the survey were the drivers who had strong views on fatigue that they wished to convey. However, there were a number of survey respondents who indicated that fatigue was not a problem for them, making it unlikely that only drivers suffering from fatigue/ sleepiness chose to respond to the survey. It is also possible that those who chose to complete the survey are particularly worried about, or interested in, fatigue. Another potential limitation to the survey sample is that the number of respondents working for each operator differed greatly. To some extent this is an artefact of the size of the operator, with a greater number of participants working for the larger operators. Additionally, variability in the steps taken to promote the survey between each operator would likely influence uptake.

Another limitation of the current research relates specifically to the on-road study. This study was the first of its kind to investigate fatigue on a live bus in such a busy location. However, due to the nature of real-world research, the on-road study came with a variety of logistical challenges which interfered with data collection. These issues were mainly related to the instrumented buses which often became unavailable due to mechanical faults or scheduling changes at the operator. This proved challenging as the study involved collecting data without impending the daily running of the bus service. As such, there were several instances in which full data sets could not be collected. The challenges experienced in this study demonstrates why this kind of research has not been conducted before. The fact that the current research is so novel and unique is why the work is so important and ground breaking.

A second limitation of the on-road study relates to the self-reported sleepiness and stress scores. Before each drive, participants were reminded to report their sleepiness score followed by their stress score. However, as the researchers did not want to interrupt the participant whilst they were driving, participants were not reminded of this order every time they reported their scores. There is therefore a possibility that drivers may have reported these scores in the wrong order.

A general limitation is that the current research did not focus on any particular cultural or religious events, such as Ramadan, which many drivers may observe. The observance of such festivals may lead to potential further fatigue as a result of dietary requirements, however data for all of the research tasks was collected outside of this time period.

A final limitation in this project relates to the proposed solutions. As discussed in section 4, the solutions proposed in this report have not yet been evaluated. This is because the research into bus driver fatigue is currently very limited. As such, the potential effectiveness of each solution has been determined by the expertise of the research team as opposed to controlled experimental research.

5.2 Future research

In linking further research to the limitations of the current project, the first potential for future research would be to implement and evaluate the potential solutions discussed in this report. In order to establish the effectiveness of any solution, a formal evaluation should be conducted. This should occur by either comparing driver fatigue before and after the implementation of a given solution, or through a randomised control trial in which one group are given an intervention whilst another is not. By doing this it would be possible to establish just how effective a proposed solution is at reducing bus driver fatigue.

There are several other avenues for potential future research in this area, these include:

- Expanding the on-road study by collecting further data.
- Exploring the relationship between bus drivers, and controllers (an issue which arose in several research tasks in the current project).
- Including shift schedulers in the research.
- Investigating fatigue/ sleepiness specifically amongst night bus drivers.
- Conducting a dedicated evaluation on fatigue detection technology currently available.
- Considering the differences in fatigue between intercity and suburban bus routes.
- Exploring the differences between experienced and inexperienced bus drivers.
- Comparing, and learning from, fatigue policies used in other transport modes such as rail and trucking.

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8 Appendix

Appendix A: Summary of the 26 papers specifically considering fatigue or sleepiness in bus drivers included in the literature review

Fatigue experience in bus drivers			
Reference	**Method**	**Main Results**	**Key Discussion/Conclusion**
Biggs, Dingsdag, & Stenson (2006)	Questionnaire	Several fatigue variables were indicated, including unrealistic schedule, cabin ergonomics, and shift cycles.	The impact of all factors was discussed. Amongst these, two stand out: fatigue related to unrealistic scheduling and the effect of managerial support on fatigue.
Biggs, Dingsdag, & Stenson (2009)	Semi-structured interview – focus groups	Nine causation factors were identified.	1) support from management 2) ticketing issues 3) interaction with passengers 4) cabin ergonomics; 5) tight route schedules 6) turn-around and shift irregularity 7) extended shift cycles 8) interactions with other road users 9) extended commute times
Vennelle, Engleman, & Douglas (2010)	Questionnaire	20% of drivers reported ESS>10, 12% of them fell asleep at the wheel at least once/month, 7% had had an accident, and 8% of them experienced a near miss due to sleepiness while driving.	Results showed a high rate of sleepiness and sleep-related accidents amongst bus drivers, as well a potentially high rate of obstructive sleep apnoea/hypopnea syndrome (OSAHS).
Sando, Mtoi, & Moses (2010)	Questionnaire, and analysis of incident reports and operator schedules	Drivers under split shift are more susceptible to fatigue, with inadequate rest time possibly contributing to fatigue.	Suggested that the bus operators implement fatigue detective technologies as well as improved policies.
Liendo, Castro, & Castro (2010)	Questionnaire	43% to 48% of the bus drivers sleep less than 7 hours a day. The most frequently admitted time of the day for having or	The fatigue and sleepiness levels were similar between formal and informal drivers.

		almost having an accident was 0100 to 0400 in the morning. 16% had levels of sleepiness.	
Abdullah & Von (2011)	Questionnaire	Bus accidents were significantly related to working schedule and working conditions.	That the buses, working schedule, and working conditions need to be improved to reduce the accident rate in Malaysia.
Diez et al. (2011)	Multiple methods including questionnaire, actigraphy, heart rate recording during a shift, PVT	Under sleeping was noted particularly amongst drivers working morning shifts. This group also showed slower reaction times.	Sleep hygiene and sleep education are needed to ensure that drivers are fully alert during their duty.
Mohamed et al. (2012)	Qualitative impact assessment	The consideration to ban early-hour schedules could result in further negative impacts on overall road safety, if aspects such as driving and work hours, and the need for driver rest facilities, are not addressed.	Highlights the need for a more holistic approach to prevent fatigue-crashes in Malaysia.
Makowiec-Dabrowska et al. (2015)	Questionnaire (Fatigue test questionnaire)	The fatigue profile after work was significantly higher than before work, but was not affected by route type. 7 fatigue symptoms were significantly higher after the “difficult” route. The level of fatigue was correlated with job characteristics.	The relationship between fatigue symptoms, job features, and lifestyle indicates both employees and employers are responsible for fatigue in bus drivers. The questionnaire used is a sensitive and useful tool for bus driver fatigue assessment.
Anund, Ihlström, Fors, Kecklund, & Filtness (2016)	Questionnaire	Driver sleepiness is prevalent among city bus drivers. 19% of drivers had to fight to stay awake whilst driving the bus 2-3 times/week +, and 45% 2-4 times/month.	Severe sleepiness was common amongst city bus drivers. Highlighted the importance of mitigating driver sleepiness and the need for fatigue risk management programmes for city bus drivers, involving

			organisational and individual countermeasures.
Deza-Becerra et al. (2017)	Questionnaire (inc. Epworth Sleepiness Scale)	9% of drivers slept less than 6h/day. 74% drivers experienced fatigue, 25% drivers experienced sleepiness, and 35% drivers had experienced nodding, while driving. Nodding and experience of driving (years) were associated with an accident or near miss. Drivers often slept in inappropriate places which impacted sleep quality.	Fatigue and sleepiness, as well as accidents or near misses occurred frequently in bus drivers. Highlighted the need for an improved system which ensures adequate rest for drivers, guidelines for schedules, and educational interventions.
Ihlström, Kecklund, & Anund (2017)	Questionnaire	36% of drivers reported split-shifts to be an issue, reporting poorer health, increased stress, interference with social life, reduced sleep quality, persistent fatigue, and lower general work satisfaction compared to those who did not find split shifts a problem.	In general, split-shift work schedules were not associated with increased stressed, poorer health and negative psychosocial work factors. However, individual differences were important as 1/3 reported problems working split shifts and experienced the above issues.
Lee, Kim, Byun, & Jang (2017)	Questionnaire (inc. Karolinska Sleepiness Scale)	No statistical differences between KSS scores for first and morning periods. Alternating day shift associated with severe sleepiness from lunch to last driving period.	Alternative day shift drivers experienced more irregular work schedules and longer working hours, and therefore suffered from more sleepiness.
Ahlström, Lövgren, Nilsson, Willstrand, & Anund (2018)	Field Test (Eye tracking, physiology, subjective rates, and video)	Dynamic steering significantly reduced required muscle activity while turning.	Muscle activity was reduced due to the use of dynamic steering, and the bus drivers believe the incorporation of this steering would reduce neck and shoulder issues.

Anund, Fors, Ihlström, & Kecklund (2018)	Real-world bus test (using EEG, camera, and KSS)	An increase in sleepiness was experienced in the afternoon by those drivers who had worked that morning, compared to being off duty in the morning. Vigilance response also significantly increased with split shift working.	Drivers working split-shifts experience sleepiness during the afternoon. Countermeasures are needed to ensure safe driving during split-shifts.
Kim, Jang, Kim, & Lee (2018)	Real-world bus test (using heart rate measures, and the Fatigue Risk Index, FRI)	Actual working hours of drivers were longer than the maximum acceptable working time (the maximum time workers can sustain their workload without physical fatigue). Fatigue index of WR schedule (every other day) was high, ranging from 45.2 to 54.4, and risk index was 1.8, which was higher than other schedules.	The WR schedule (working every other day) caused over work in drivers and showed high fatigue and risk scores according to the fatigue and risk indices. Regulations and policies for drivers working time should be reviewed. Restricting driving time may help to reduce driver fatigue and the risk of accidents.
Chaiard, Deeluea, Suksatit & Songkham (2019)	Survey made up of three questionnaires (sleep quality, risk of sleep apnoea, sociodemographic, lifestyle behaviours and work data)	60% of drivers reported poor sleep quality. An increased risk of poor sleep quality was predicted by marital status, alcohol consumption, lack of exercise, night driving, and rotating shifts patterns.	There is a high prevalence of poor sleep quality amongst Thai bus drivers, this is likely caused by a combination of factors which includes shift work.
<u>Fatigue countermeasures and prevention strategies for bus drivers</u>			
Reference	**Methods**	**Main Results**	**Key Discussion/Conclusion**
Machin & Hoare (2008)	Questionnaire	That workload was an important predictor for the drivers' need for recovery.	Fatigue management strategies should focus on the assessment and remediation of bus drivers' response strategies.
Razmpa, Niat, & Saedi (2011)	Questionnaire (inc. Epworth Sleepiness Scale,	Sleep problems were a common occurrence amongst drivers, and had a	The results highlight the importance of sleep in relation to bus driving. Attention needs to be paid

	insomnia, and apnoea index)	significant relationship with crash history	to treating sleep disorders, as well as occupational sleep hygiene of bus drivers.
Sang & Li (2012)	Experimental testing (Psychology Fatigue Measurement System)	The bus driver's performance decreased over time in terms of 4 indicators: flash fusion frequency, reaction time, speed perception, and attention level.	That bus driver's reaction time began to decrease sharply after 4 hours of duty.
Santos, Bittencourt, de Assis Viegas, & Gaio (2013)	Questionnaire (inc. Epworth Sleepiness Scale), and attention tests	Drivers' sleepiness was correlated with BMI, and attention level was correlated with age.	Sleepiness is a common risk factor for professional drivers.
Wang & Wang (2013)	EEG analysis in real driving environment and questionnaire	The relationship between driver fatigue and associated EEG characteristics are analysed.	Driver fatigue state changes can be effectively detected through EEG fatigue state index F.
Krishnaswamy, Chhabria, & Rao (2016)	Questionnaire (inc. Epworth Sleepiness Scale)	Although 62.8% of drivers experienced sleepiness, no drivers reported causing accidents due to sleepiness. Various coping strategies are mentioned. Post-shift sleep was studied, concluding that initiating and maintaining sleep are major issues.	Night bus drivers have a high incidence of night-time sleepiness and daytime sleep disruptions. Highlighted the need for shift work education and alertness testing for shift workers in critical professions.
Mandal, Li, Wang, & Lin (2017)	Vision-based fatigue detection system	The proposed method was able to distinguish the drowsy and sleepy states compared to normal states of driving.	The system may be able to monitor driver's attentional levels effectively without additional cameras.
Kim et al. (2017)	Questionnaire	Out of 842 bus drivers, 13.2% reported ESS score >10, 68.4% experienced poor sleep quality, and 10.2% had a	Poor sleep quality, insomnia and high risk for OSA are three factors associated with excessive daytime sleepiness amongst Korean bus drivers.

		moderate to severe insomnia.	
Wang & Wu (2019)	Schedule analysis, case study approach	Driver scheduling of multi-day driving patterns effects driver's crash risk. Driving in the afternoon or early morning for two consecutive days, and following 24h rest, returning to work in the morning, afternoon, or early morning were patterns with the greatest crash risk. Rescheduling may help to reduce overall fleet crash risk.	A mathematical optimisation model was developed. Rescheduling using the developed could reduce the crash incidence by approximately 30%. Highlighted the need for further research into why multi-day driving patterns are associated with higher crash risk.

Appendix B: Bus driver focus group question guide

Introduction

- Welcome and thanks for coming
- Introduce X and X – Loughborough's role – project overview - discussion groups to get driver perspective on what it is really like.
- Informal discussion about your experiences of fatigue and how it is managed at work – your feedback is really important for the future fatigue management in the industry, so please feel free to have your say and be honest.
- For us it is important that you talk to each other and share experience, we are only observing and not the experts. You are.
- All information you provide will be kept confidential, no individuals will be identified in any reports
- Can we audio record the discussion?

Introductory Question

- Before we go into specific fatigue questions, we'd just like to learn a little bit about you and your backgrounds, whatever you're prepared to share. We are interested in what brought you to into bus driving, how long you've been driving buses and what shift pattern are you working?

Does fatigue occur, is it a problem

- If I say 'fatigue' what do you think about? [PROJECT DEFINITION: a psychological and/or physical impairment experienced by a driver which has the potential to reduce optimal performance. Fatigue is considered to be multifaceted, encompassing pressures from both the sleepiness related to human biology and task related fatigue. So it may be:
  - Sleepiness due to insufficient sleep and/or time of day
  - Task related fatigue due to the nature of work driving a bus in city environment resulting in an inability to continue or impairment in performance caused by
    - Time on task due to the same activity going on too long
    - Overload of cognitive demands during times of exposure to demanding workload.
    - Underload of cognitive demands during times of monotonous activity.
    - Physical muscle fatigue due to physical exertion, for example steering the bus.]
- What has been your general experience of fatigue at work? Could you describe a situation where you or anyone you know has suffered from driver fatigue during work?
- To what extent do you believe fatigue/sleepiness is a problem in your industry?

Consequences of fatigue

- In what way do you think fatigue/sleepiness influences safety at work?
- What is your biggest safety concern if you are fatigued/sleepy at work?
- How is your driving affected when you feel fatigue/sleepy? In what way do you notice a difference in yourself and your driving when working days you feel very alert compared to days when you feel sleepy?

Strategies for managing fatigue

- Do you take any measures to ensure you are not fatigued/sleepy at work? PROMPT: plan to sleep before shifts, drink coffee, etc.
- What do you do if you feel fatigued/sleepy?
- Could you please describe how you prepare yourself to avoid fatigue/ sleepiness before a shift?

Causes of fatigue

- What issues might cause you to be fatigued at work?
- Does the route you drive cause you stress/fatigue? Is there a difference when it is a new route or one you drive regularly?

Workplace culture surrounding fatigue

- What would you do if you felt fatigued/sleepy at work?
- Could you describe how you communicate with your employer or supervisor if you were fatigued/sleepy at work? What would you expect their response to be?
- What do people do if they are too tired to work? PROMPT: Would you phone in sick? Would you say you were tired or give a different reason?

Shift patterns/overtime

- Are shift patterns fixed or can you/do you swap shifts? How does this influence fatigue?
- Are there any specific times of the day, situations, or points in a shift/shift pattern when you are most likely to feel fatigued/sleepy or that your alertness is particularly challenged?*
- From experience can you tell us which features of rotas cause you the most fatigue? E.g. changing start times, rotation through earlies, middles and lates, or rest days being reduced by long shifts either side.
- How much extra overtime can you pick up? Does this influence your fatigue?

- Does anyone check your total hours resulting from overtime? What motivates your choice of how much overtime to take on?**

Sleep/fatigue outside work

- Does your non-work time (including commute) influence how fatigued/sleepy you feel?
- What factors influence how much you would sleep when not at work?
- Can you describe how you switch off and relax at the end of the day after work?

Stress/pressure

- What aspects of the job are most stressful for you? Do these link to feelings of fatigue?
- Do you feel under pressure to meet the route timetable? How does this affect your stress/fatigue?

* **Need to find this out for the on-road study**
** **Do any swap on purpose to end up below the minimum hours to get paid for not working? Only applies where there is a minimum wage.**

BACK-UP QUESTIONS:

- How much notice do you get about shift pattern/holiday allocation? Is there any flexibility to swap?
- Has your attitude and approach to picking up overtime changed over time? If yes, what factors have influenced it?
- Are the ways you cope with fatigue individually developed, learnt from colleagues, or taken from advice from your employer?
- Have you had training/advice on how to handle fatigue? If not, would you like some, and what would you like it to cover?
- Could you describe your view on violence and threats at work, and how these influence you?

Closing

- Any other comments/questions?
- Thanks

Appendix C: Manager interview question guide

Introduction

- Thank you for agreeing to the interview
- Introduce yourself – Loughborough's role – project overview – interviews to get manager perspective on workplace culture around fatigue
- Informal discussion about your experiences of fatigue and how it is managed at work – your feedback is really important for the future fatigue management in the industry, so please feel free to have your say and be honest
- All info you provide will be kept confidential, no individuals will be identified in any reports
- Can we audio record the discussion?

Introduction Question

- Before we go into specific fatigue questions, we'd just like to learn a little bit about your background – what brought you to this role?
- What does your job entail? How long have you been doing your current role?
- If I say 'fatigue', what do you think about?

What is the manager's view of the prevalence of fatigue/sleepiness among their bus drivers?

- To what extent do you believe fatigue/sleepiness is a problem in your industry?
- Have you ever experienced a driver reporting suffering from fatigue at work? If so, what happened and what did you do about it?
- What is the general culture around fatigue in your organisation?
- What do you/your company do to ensure that drivers are fit to work and not fatigued?

What do managers perceive to be the causes and consequences of fatigue/sleepiness in bus drivers?

- What issues do you think cause drivers to be fatigued at work? (PROMPT: Shift work, long hours, monotonous tasks, stress, threats/violence)
- If a driver is fatigued, how do you think this would influence their driving?
- To what extent do you think fatigue/sleepiness influences safety at work? What is your biggest safety concern relating to sleepy drivers?
- Do you think there is a link between fatigue and accidents?

What strategies are used to manage fatigue/sleepiness at work?

- What do you believe the company is doing well in the management of fatigue/sleepiness?
- What do you believe the company is doing poorly in the management of fatigue/sleepiness?

- What are drivers expected to do if they feel fatigued/sleepy while driving? Do you think they follow this?
- What would you do if one of your drivers reported that they were too tired to come into work?
- If a driver came to you with concerns about fatigue how would you handle this? In your experience would drivers be likely/unlikely to come to you with this type of issue?
- Does your company offer training and advice on how to handle fatigue? If so, what generally does it cover? And who is it aimed at? If not, do you think it should?
- Is fatigue considered as part of accident/incident investigation? If so what approach is taken?
- If an accident/incident investigation concluded that a driver was fatigued, what action would be taken and how would this be decided upon?

Shift patterns/overtime

- Are shift patterns fixed or does the company allow drivers to swap shifts? Do you think this has an effect on fatigue?
- What is the policy around overtime? How much extra does the company allow drivers to pick up? Do you think this has an effect on fatigue?
- Is there a difference between older and younger drivers and their requests for overtime?

Additional questions if there is time

- Does the operator impose any rules about commuting e.g. distance a driver is allowed to live from a garage or how they commute?
- Do you as a Manager have any concerns about drivers' commute times? Can this influence fatigue at work?
- What would happen if a driver was too fatigued to drive home?

Closing

- Any other comments/questions?
- Thanks

Appendix D: Bus driver survey

Questions about your work as a bus driver

1. **How long have you been working as a bus driver?**

_____

2. **Is bus driving your main job?**

☐ Yes, my only job

☐ Yes, but I also have another job

☐ No, I have another job

☐ Yes, my only paid employment but I am also studying

3. **Do you work as a bus driver full time, or part time?**

☐ Full time

☐ Part Time

4. **How many hours do you usually work during a week as a bus driver?**

_____

5. **What type of schedule/roster pattern do you have?**

☐ Fixed roster on dedicated routes

☐ Rotating roster on dedicated routes

☐ Spares (no dedicated route) on a fixed roster

☐ Spares (no dedicated route) on a rotating roster

☐ Other (please specify) _____

6. **In general, how satisfied are you with your work schedule?**

☐ Very satisfied

☐ Quite satisfied

☐ Neither satisfied nor unsatisfied

☐ Quite unsatisfied

☐ Very unsatisfied

7. Does your work schedule as a bus driver include any of the following at least once (or more) each month?

				How big a problem is this for you? *1=very small 5=very big*				
	No	*Yes*		*1*	*2*	*3*	*4*	*5*
a) Morning shift (shift that starts at 06:00 or earlier)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
b) Daytime shift (shift between 07:00 - 19:00)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
c) Evening shift (shift between 19:00 - 00:00)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
d) Night shift (at least 4 hours between 00:00 - 06:00)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
e) A rota which includes both shifts in the daytime and the evening	☐	☐	*If yes:*	☐	☐	☐	☐	☐
f) Spreadovers (more than 1.5 hours break between shifts)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
g) Less than 11 hours break between shifts	☐	☐	*If yes:*	☐	☐	☐	☐	☐
h) 6 or more working days without rest	☐	☐	*If yes:*	☐	☐	☐	☐	☐
i) More than 10 hours overtime per week (paid or unpaid)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
j) Short notice of the shift you are expected to work (less than 1 week)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
k) Variability in shift start times (e.g. starting at 9am one day, then 11am the next)	☐	☐	*If yes:*	☐	☐	☐	☐	☐
l) Bus routes running longer than they usually would due to unforeseen circumstances (e.g. traffic)	☐	☐	*If yes:*	☐	☐	☐	☐	☐

8. Please answer the following questions about your working hours as a bus driver.								
				How big a problem is this for you? 1= very small…5=very big				
	No	*Yes*		*1*	*2*	*3*	*4*	*5*
a) Do you think your working hours cause your sleep to be disturbed?	☐	☐	*If yes:*	☐	☐	☐	☐	☐
b) Do you think your working hours contribute to sleepiness when you are driving the bus?	☐	☐	*If yes:*	☐	☐	☐	☐	☐
c) Do you think your working hours are associated with any health risks?	☐	☐	*If yes:*	☐	☐	☐	☐	☐
d) Do you think your working hours are associated with an accident risk?	☐	☐	*If yes:*	☐	☐	☐	☐	☐
e) Do you think sleepiness in your work increases the risk of serious mistakes?	☐	☐	*If yes:*	☐	☐	☐	☐	☐
f) Would you say your working hours cause fatigue when driving the bus?	☐	☐	*If yes:*	☐	☐	☐	☐	☐

9. Please answer the following questions about your working hours as a bus driver.								
				How big a problem is this for you? 1= very small…5=very big				
	No	*Yes*		*1*	*2*	*3*	*4*	*5*
a) Do you think it is easy to influence your working hours?	☐	☐	*If no:*	☐	☐	☐	☐	☐
b) Do your working hours allow you to have a good work/ life balance?	☐	☐	*If no:*	☐	☐	☐	☐	☐
c) Do you think you get enough breaks at work?	☐	☐	*If no:*	☐	☐	☐	☐	☐

10. Are you able to swap shifts with other drivers?

☐ No

☐ Yes, with employer permission

☐ Yes, either with or without employer permission

a. If so, how often does this occur?

☐ Every month

☐ Every 2-3 months

☐ Every 4-6 months

☐ Once or twice a year

11. Thinking about your commute, which of the following do you use to get to work?

☐ Walk ☐ Car ☐ Train

☐ Bus ☐ Underground ☐ Cycle

☐ Other (please specify) _____

a. During your commute, how long does it take you to get to work from home?

_____

Questions about your sleep

12. In general, how would you rate your sleep in the last 3 months?

☐ Very good

☐ Quite good

☐ Neither good nor bad

☐ Quite bad

☐ Very bad

13. Have you ever been diagnosed with a disorder or condition which affects your sleep, e.g. obstructive sleep apnoea?

☐ Yes

☐ No

a. If yes, which condition or disorder?

_____

b. Have you declared this to your employer?

☐ Yes

☐ No

14. Please indicate the degree to which the following have happened to you during the last 3 months.

	Never	**Seldom** *(One or few times a year)*	**Sometimes** *(Several times a month)*	**Often** *(1-2 times a week)*	**Most often** *(3-4 times a week)*	**Always** *(5 times or more a week)*
a) Difficulty in falling asleep	☐	☐	☐	☐	☐	☐
b) Difficulty in waking up	☐	☐	☐	☐	☐	☐
c) Repeated waking up during the night with problems falling asleep again	☐	☐	☐	☐	☐	☐
d) Severe snoring (own)	☐	☐	☐	☐	☐	☐
e) Difficulty catching your breath during sleep	☐	☐	☐	☐	☐	☐
f) Interrupted breathing during sleep (sleep apnoea)	☐	☐	☐	☐	☐	☐
g) Nightmares	☐	☐	☐	☐	☐	☐
h) Not feeling rested upon waking up	☐	☐	☐	☐	☐	☐
i) Waking up too early	☐	☐	☐	☐	☐	☐
j) Disturbed or worried sleep	☐	☐	☐	☐	☐	☐
k) Involuntary tremors in the legs that interfere with sleep	☐	☐	☐	☐	☐	☐
l) Overly light sleep	☐	☐	☐	☐	☐	☐
m) Being constantly tired throughout the day	☐	☐	☐	☐	☐	☐
n) Physical tiredness	☐	☐	☐	☐	☐	☐
o) Mental fatigue	☐	☐	☐	☐	☐	☐
p) Feeling sleepy at work	☐	☐	☐	☐	☐	☐
q) Feeling sleepy during leisure time	☐	☐	☐	☐	☐	☐
r) Involuntary falling asleep (e.g. microsleep) at work	☐	☐	☐	☐	☐	☐
s) Involuntary falling asleep (e.g. microsleep) during leisure time	☐	☐	☐	☐	☐	☐
t) The need to fight to stay awake during daytime	☐	☐	☐	☐	☐	☐

15. How much sleep do you ideally need between shifts to be able to drive safely/ feel rested?

_____

16. How much sleep do you usually get between shifts?

_____

17. How often do you take a nap (a short sleep during the day)?

☐ Almost never

☐ A few times a month

☐ Once a week

☐ A few times a week

☐ Every day/ almost always

a. If you nap, on average how long do you nap for?

_____

18. How many cups of coffee do you drink on average in a work day? (e.g. 0, 1, 2 etc.)

_____

19. How many cans of energy drink (e.g. redbull, monster) do you drink on average in a work day? (e.g. 0, 1, 2 etc.)

_____

20. Do you ever take caffeine tablets (e.g. ProPlus) on a work day?

☐ Never

☐ A few times a month

☐ At least once a week

☐ A few times a week

☐ Everyday/ almost always

Questions about your health

21. In general, how would you rate your health?

☐ Very good

☐ Quite good

☐ Neither good nor bad

☐ Quite bad

☐ Very bad

22. On a scale from 1-10, where 1 is the lowest level, and 10 is the highest, how stressed would you rate yourself over the last 3 months?

1 2 3 4 5 6 7 8 9 10

23. Are you a smoker?

☐ Non-smoker, never been a smoker, only smoked a few times

☐ Non-smoker, but previously have been a smoker (not for the last 6 months or more)

☐ Smoker

☐ E-cigarette user

24. How often do you exercise in your leisure time?

☐ Almost never, mostly inactive, occasional walks

☐ Seldom or irregular exercise, cycle or walk sometimes

☐ Regular, low impact exercise, cycle to work, walk often

☐ Regular, high impact exercise, at least twice per week, (sweating to a high degree)

☐ Competitive exercise, training or competing

25. Do you take sleeping pills to help you sleep?

☐ No

☐ Yes, sometimes

☐ Yes, on a regular basis

26. Please read each statement and answer corresponding to how you have been feeling on average during the last 3 months

	Not at all	Sometimes	Quite often	Almost always
a) There are some days when I feel hyper all the time	☐	☐	☐	☐
b) There are days when I feel very stressed, at the limit of what I can handle	☐	☐	☐	☐
c) I have difficulties relaxing during leisure time	☐	☐	☐	☐
d) I am often tense	☐	☐	☐	☐
e) I often feel worried	☐	☐	☐	☐
f) I am often restless	☐	☐	☐	☐
g) I do not feel rested after being at home and resting for a couple of days	☐	☐	☐	☐
h) I have days when I feel stressed all the time	☐	☐	☐	☐

Questions relating to yourself as a bus driver

27. How much enjoyment do you get from bus driving? Please indicate on the scale below where 1 is no enjoyment (driving is for income only), and 10 is high enjoyment (driving is fun)

1 2 3 4 5 6 7 8 9 10

28. On a scale from 1-10, where 1 is the lowest level, and 10 is the highest, how stressed do you feel daily while driving the bus?

1 2 3 4 5 6 7 8 9 10

29. How often do you have to fight sleepiness in order to stay awake while driving the bus?

☐ Never

☐ Occasionally

☐ 2-4 times a month

☐ 2-3 times a week

☐ 4 or more times a week

30. In the past 12 months, have you had to stop the bus due to fatigue?

☐ Never

☐ Once

☐ Twice

☐ Three times

☐ More than three times

31. In the past 12 months, have you wanted to stop the bus due to fatigue, but been unable to?

☐ Never

☐ Once

☐ Twice

☐ Three times

☐ More than three times

32. In the past 12 months, have you fallen asleep whilst driving the bus?

☐ Never

☐ Once

☐ Twice

☐ Three times

☐ More than three times

33. In the past 12 months have you have a 'close call' on the road while driving the bus because you were sleepy?

☐ Never

☐ Once

☐ Twice

☐ Three times

☐ More than three times

a. Do you think your employer knows that this close call was because you were sleepy?

☐ Yes

☐ No

34. In the past 12 months, have you had a road crash while driving the bus because you were sleepy?

☐ Never

☐ Once

☐ Twice

☐ Three times

☐ More than three times

a. Do you think your employer knows that this crash was because you were sleepy?

☐ Yes

☐ No

35. In the last 10 years have you experienced an incident or crash where sleepiness was partly or solely to blame? This could be whilst driving the bus, or whilst driving your own vehicle.

☐ No

☐ Yes, once

☐ Yes, several times

☐ Do not remember

36. In the past 12 months when driving the bus, have you ever experienced any of these symptoms? Select all that apply

☐ Yawning

☐ Frequent eye blinks

☐ Difficulty keeping eyes open

☐ Difficulty in concentrating on driving

☐ Needing to change position frequently

☐ Slower reactions to traffic events

☐ Increased variation in speed

☐ Dreamlike state of consciousness

☐ Head nodding

☐ Other (please specify) _____

37. What time of day are you most likely to feel sleepy whilst driving the bus? You can select more than one option.

☐ Early morning (04:00 – 08:00)

☐ Mid-morning (08:00 – 12:00)

☐ Afternoon (12:00 – 16:00)

☐ Early evening (16:00 – 20:00)

☐ Late evening (20:00 – 00:00)

☐ Night (00:00 – 04:00)

☐ I don't feel sleepy whilst driving the bus

38. At what point in your shift do you feel most sleepy whilst driving the bus? You can select more than one option.

☐ When you start driving

☐ Before a break

☐ After a break without food

☐ After a break with food/ lunch

☐ At the end of your shift

☐ Other (please specify) _____

☐ I don't feel sleepy whilst driving the bus

39. At what point in your shift rotation do you feel most sleepy when driving the bus? You can select more than one option.

☐ First day back after a rest day

☐ Two days back after a rest day

☐ Last day of work before a rest day

☐ The first day of a new type of shift (e.g. the first early after a late)

☐ Other (please specify) _____

☐ I don't feel sleepy whilst driving the bus

40. Do you do anything whilst driving the bus to reduce sleepiness and keep yourself alert? If so, what do you do? Select all that apply.

☐ Stopping for a break

☐ Opening a window

☐ Drinking caffeine

☐ Eating sweet or a sugary snack

☐ Chewing gum

☐ Singing/ talking to yourself

☐ Body movements whilst driving

☐ Exercise

☐ Music

☐ Turning on the fan or AC

☐ Driving slower

☐ Driving more actively

☐ Driving faster

☐ Make an excuse to stretch (e.g. check the mirrors or check the back safety window even though you know there is nothing wrong with it)

☐ Other (please specify) _____

☐ I do not use any techniques to reduce sleepiness

41. Do you do anything when you are not driving the bus to reduce sleepiness and keep yourself alert (e.g. during breaks, between shifts, at bus stops)? If so, what do you do? Select all that apply.

☐ Going for a short walk

☐ Opening a window

☐ Drinking caffeine

☐ Eating sweet or a sugary snack

☐ Chewing gum

☐ Singing/ talking to yourself

☐ Exercise

☐ Music

☐ Turning on the fan or AC

☐ Make an excuse to stretch (e.g. check the mirrors or check the back safety window even though you know there is nothing wrong with it)

☐ Other (please specify) _____

☐ I do not use any techniques to reduce sleepiness

42. How often do you have to actively do something to keep yourself alert when driving the bus?

☐ Never

☐ Occasionally

☐ 2-4 times a month

☐ 2-3 times a week

☐ 4 or more times a week

43. On a typical work day, do you bring your own food or buy something during the day?

☐ Bring my own food

☐ Buy something from my employers canteen

☐ Buy food from a shop or cafe

☐ I don't have food at work

a. If you eat a meal during your work day, which of the following would you usually eat?

☐ Packet food/ meal deal (e.g. a packet sandwich with a snack and a drink)

☐ A small hot meal (e.g. a jacket potato)

☐ A large hot meal (e.g. meat and vegetables)

44. Do you encounter any of these difficulties during your scheduled rest periods?

				How big a problem is this for you? 1=very small…5=very big				
	Yes	*No*		*1*	*2*	*3*	*4*	*5*
a) Nowhere to sit	☐	☐	*If yes:*	☐	☐	☐	☐	☐
b) Inability to access a toilet	☐	☐	*If yes:*	☐	☐	☐	☐	☐
c) Insufficient time to eat	☐	☐	*If yes:*	☐	☐	☐	☐	☐
d) Insufficient time to rest	☐	☐	*If yes:*	☐	☐	☐	☐	☐
e) Late running of the bus leading to a shorter break	☐	☐	*If yes:*	☐	☐	☐	☐	☐
f) No access to an indoor rest area	☐	☐	*If yes:*	☐	☐	☐	☐	☐

Background Questions

45. What is your age?

_____

46. What is your gender?

☐ Male ☐ Female ☐ Other ☐ Prefer not to say

47. What is your height?

_____

48. What is your weight?

_____

49. What is your current relationship status?

☐ Single

☐ Living with a partner

☐ Married/ Civil partnership

☐ Separated/ Divorced

☐ Widowed

☐ Prefer not to say

50. Do you have children who live with you at home?

☐ Yes

☐ No

a. If yes, please list current ages

_____

51. What is the postcode of your home address?

_____

52. What is your highest level of education?

☐ No schooling completed

☐ Secondary school

☐ Sixth form or college

☐ Trade/ technical/ vocational training

☐ Bachelor's degree

☐ Master's degree

☐ Doctorate degree

53. Which operator do you work for?

☐ Abellio

☐ Arriva

☐ Go Ahead

☐ HCT group

☐ Uno/ Herts Uni

☐ Metro line

☐ RATP Dev

☐ Stage coach buses

☐ Sullivans

☐ TowerTransit

54. If you have any further comments relating to any of the questions in this survey, or any further comments about fatigue in general, we would be happy to hear them.

Appendix E: On-road study background questionnaire

For the on-road study, the following questions from the bus driver survey (Appendix D) were used:

- Questions 1-9
- Questions 11- 13a
- Questions 14-17
- Questions 21-22
- Questions 24-25
- Question 27
- Questions 29 -32
- Question 34
- Questions 37-38
- Questions 45-48
- Question 52
- Question 54

In addition, two further questions were added (see below)

1. **One hears about "morning" and "evening" types of people. Which one of these types do you consider yourself to be?**

☐ Definitely a morning type

☐ Rather more a morning than an evening type

☐ Neither a morning type nor an evening type

☐ Rather more an evening than a morning type

☐ Definitely an evening type

2. **How much sleep do you ideally need each night to feel rested?**

_____

Appendix F: After drive questionnaire used in the on-road study

Please answer the following questions about your experience

1. How difficult did you find it to stay awake while driving?

Not at all difficult						Very difficult
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

2. How stressed did you feel while driving?

Not at all stressed						Very stressed
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

3. Did you feel worried while driving?

Not at all worried						Very worried
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

If you marked 5 or higher on any of the questions above, please describe the reason?

_____

_____

_____

_____

_____

4. How similar was this drive compared to an everyday drive on the same route?

Not at all similar						Very similar
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

	Yes	No	Don't know
5. Did you lose control of the vehicle at any time during the drive?	☐	☐	☐
6. Did you lose awareness of the surrounding traffic at any time of the drive?	☐	☐	☐
7. Did you experience sleepiness at any time of the drive?	☐	☐	☐
8. Did you use any countermeasure to stay awake while driving? **If yes,** what did you do to stay awake? _____ _____ _____	☐	☐	☐

9. Was there any experience or situation today that influenced you're driving and made the drive more demanding?

	No influence	Some influence	Moderate influence	Large influence	Very large influence
Stressed, because _____ _____	☐	☐	☐	☐	☐
Sleepy, because _____ _____	☐	☐	☐	☐	☐
Inattentive, because_____ _____	☐	☐	☐	☐	☐
Other, because_____ _____	☐	☐	☐	☐	☐

10. Did anything influence your wellbeing in a negative way today? (for example headache, pain in the stomach etc.)

☐**Yes** ☐**No**

If yes, what was the main reason?

_____

Appendix G: On-road technical appendix

Physiological measurements

Physiological data were collected using a Vitaport 3 system. Electrodes for electrooculography (EOG) to record and detect blinks, and electrocardiography (ECG) to record electrical activity of the heart were placed on the face and on the body (see Figure 2.2 in the main body of the text). The electrodes were placed mainly on the right side of the face, which was facing away from the passengers. Heartbeats (R-peaks) were extracted from the ECG signal and the resulting R-R time series was used to derive several heart rate variability (HRV) metrics (Shaffer & Ginsberg, 2017; Laborde, Mosley & Thayer, 2017). The main idea is that stress will increase the heart rate and reduce the heart rate variability, whereas sleepiness and fatigue will reduce the heart rate and increase the heart rate variability. In this study, the HRV metric root mean square of successive R-R differences (RMSSD) will be reported. The blink parameters were extracted from the vertical EOG signal with an automatic blink detection algorithm (Jammes, Sharabty & Esteve, 2008). Four blink duration-based parameters were calculated; the mean, standard deviation and 95th percentile blink duration, and the percentage of eye blinks with a duration longer than 0.150 seconds (Fors et al., 2011).
For the analysis all physiological parameters were calculated in five-minute intervals for each drive to mirror the fact that KSS and SUS were reported every five minutes.

Statistical analysis

Results from the sleep and wake diaries were compared between rest days, morning shifts and daytime shifts using GLM ANOVA and Chi-square tests. Differences in sleep patterns, measured with actigraphy, before the morning and daytime drive were analysed with paired samples t-tests.

The data gathered from the on-road study was unbalanced in terms of time driven during morning shifts compared to daytime shifts. The morning drives were on average shorter than the daytime drives. To achieve a balanced data, data from minute 1 to minute 49 of each drive was included in the analysis, which corresponded to the time driven during the fastest morning drives. The purpose of this was to allow direct statistical comparisons between the early morning and daytime drives. In cases where the daytime drives lasted longer than 49 minutes, it would not be possible to compare them to an early morning drive.

Driver physiology and driver behaviour during the driving were analysed with a GLM ANOVA considering three types of comparison. The two conditions were compared (Morning/ Day); within each drive the time into the analysis period was considered as time on task (5-10-15-20-25-30-35-40-45 minute) and the direction of travel toward city centre (yes/no). The reason for the latter was the effect of traffic density in different regions of the route. Participant was used as a random factor. The considered variables were: Sleepiness, Stress, Blink duration, Heart rate variability (HRV RMSSD), Percentage of long blink durations (>0.15 s), Speed (mph), Accelerations and Decelerations (m/s^2). The model included both main effects and 2-way interactions.

References

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Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart rate variability and cardiac vagal tone in psychophysiological research–recommendations for experiment planning, data analysis, and data reporting. *Frontiers in psychology*, *8*, 213.

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Appendix H: Bus operator background questionnaire.

Bus operator background information questionnaire

The purpose of this questionnaire is to gather background information from bus operators in London. The questions relate to central company policy and governance. In subsequent stages of the work local level managers and drivers will be consulted.

Answers to these questions will help inform the work undertaken by Loughborough University and VTI about bus driver fatigue under contract for TfL. Information in all reports provided to TfL will be anonymous. If you have any questions about this work please contact Dr Ashleigh Filtness A.J.Filtness@lboro.ac.uk

Questions	Space for your answers
Operator company name	
Job tile/role of person completing this questionnaire	

All questions relate to bus operations in London only.

Questions about your drivers	
1. How many bus drivers do you employ?	
2. What is the average length of time bus drivers have been employed?	
3. Approximately what proportion of your drivers are not native English speakers?	
4. Is there any prevalent language (other than English) spoken amongst your bus drivers to which you would recommend we translate written materials to when contacting drivers?	
5. What proportion of your bus drivers are female?	
6. Are drivers subject to medical fitness tests, if so how regularly?	
7. Do drivers have a fixed base, or do they work out of a range of garages/ depots?	
8. How are drivers paid (e.g. day rate, annual salary)? If mixed, what proportion of drivers are salaried vs casual?	
9. Is there an organisation requirement for drivers to confirm fitness to drive at the start (or during) a shift? Is so what does this include?	
Questions about your busses	
10. How many buses are in your London fleet?	
11. What make/model of buses do you operate?	
12. How many garages/depots do you have in London?	

Questions about your organisation operations	
13. What hours of the day do your buses operate? (are operations 24h?)	
14. If night time driving is required, what daytime hours does your organisation define as being night shift?	
15. Are drivers offered financial incentive to work nights?	
16. What type of shifts do drivers in your organisation work, i.e. day shifts only, night shifts only, split shifts, or mixed work?	
17. How are shift schedules planned?	
18. How are drivers allocated shifts (are drivers permitted to select their own preferred shifts)?	
19. At what level is responsibility for compliance with Hours of Work Rules held? E.g. driver, local manager, shift scheduler etc	
20. Is there a formal company policy or training given to drivers on what to do if they feel unwell while driving the bus? If so what is this? (or would this be handled at individual manager level?)	
21. Is there any formal fatigue management content in your driver training program?	
22. Does your crash/incident reporting/recording/investigation system include consideration of driver fatigue?	

Appendix I: Complete results obtained in the bus driver survey.

Questions about your work as a bus driver

1. **How long have you been working as a bus driver?**

2 months – 43 years (M = 10.52 years, SD = 8.47 years)

2. **Is bus driving your main job?**

☐ Yes, my only job – 97%
☐ Yes, but I also have another job – 0.5%
☐ No, I have another job – 0.3%
☐ Yes, my only paid employment but I am also studying – 0.8%

3. **Do you work as a bus driver full time, or part time?**

☐ Full time – 95.7% ☐Part Time – 2.7%

4. **How many hours do you usually work during a week as a bus driver?**

8 – 75 hours (M = 44.35, SD = 8.21)

5. **What type of schedule/roster pattern do you have?**

☐ Fixed roster on dedicated routes – 37.5%
☐ Rotating roster on dedicated routes – 42.9%
☐ Spares (no dedicated route) on a fixed roster – 8.1%r
☐ Spares (no dedicated route) on a rotating roster - 9.3%
☐ Other (please specify) - 1.8%

6. **In general, how satisfied are you with your work schedule?**

☐ Very satisfied – 7%
☐ Quite satisfied – 21.5%
☐ Neither satisfied nor unsatisfied 25.1%
☐ Quite unsatisfied – 24.4%
☐ Very unsatisfied – 21.7%

7. **Does your work schedule as a bus driver include any of the following at least once (or more) each month?**

				How big a problem is this for you? 1=very small 5=very big				
	No	**Yes**		**1**	**2**	**3**	**4**	**5**
Morning shift (shift that starts at 06:00 or earlier)	13.7%	80.7%	If yes:	32.1%	14.7%	19.8%	11%	14.8%
Daytime shift (shift between 07:00 - 19:00)	11.6%	79.8%	If yes:	34.2%	17.3%	21.1%	8%	10.5%
Evening shift (shift between 19:00 - 00:00)	21.5%	67.8%	If yes:	22.9%	14%	18.2%	11.8%	23.3%
Night shift (at least 4 hours between 00:00 - 06:00)	67.4%	18.6%	If yes:	22.2%	9.1%	11.9%	11.1%	31.3%
A rota which includes both shifts in the daytime and the evening	25.9%	62.9%	If yes:	10.5%	12.6%	21.5%	14.7%	29.3%

Spreadovers (more than 1.5 hours break between shifts)	26.8%	62.7%	If yes:	19.1%	12%	17.1%	10.7%	30.9%
Less than 11 hours break between shifts	39.6%	48.5%	If yes:	9.3%	7.3%	12.5%	14.9%	45.3%
6 or more working days without rest	13.5%	78.1%	If yes:	9.6%	7.9%	12.1%	15.6%	43.2%
More than 10 hours overtime per week (paid or unpaid)	50.6%	37.6%	If yes:	21.2%	14.3%	19.6%	9%	22.2%
Short notice of the shift you are expected to work (less than 1 week)	56.7%	32.5%	If yes:	11.1%	11.1%	13.9%	13.2%	35.7%
Variability in shift start times (e.g. starting at 9am one day, then 11am the next)	21.5%	68.8%	If yes:	7.3%	10.2%	16.9%	18.4%	36.7%
Bus routes running longer than they usually would due to unforeseen circumstances (e.g. traffic)	9.3%	82.3%	If yes:	8.8%	11.7%	17.3%	15.1%	37.8%

8. Please answer the following questions about your working hours as a bus driver.

				How big a problem is this for you? 1= very small…5=very big				
	No	**Yes**		**1**	**2**	**3**	**4**	**5**
Do you think your working hours cause your sleep to be disturbed?	13.9%	83.3%	If yes:	1.8%	4.4%	12.8%	18.8%	56.4%
Do you think your working hours contribute to sleepiness when you are driving the bus?	17.1%	78.8%	If yes:	3.3%	7.9%	14.6%	16.4%	51.7%
Do you think your working hours are associated with any health risks?	14.3%	81.5%	If yes:	2.6%	4.4%	15.6%	18.5%	52.7%
Do you think your working hours are associated with an accident risk?	16.1%	79.2%	If yes:	3.5%	7.4%	14%	17.7%	51.3%
Do you think sleepiness in your work increases the risk of serious mistakes?	7%	88.8%	If yes:	3.7%	4.7%	10.8%	15.6%	58.3%
Would you say your working house cause fatigue when driving the bus?	11.5%	84.4%	If yes:	3.1%	6%	15.1%	16.5%	52.9%

9. Please answer the following questions about your working hours as a bus driver.

				How big a problem is this for you? 1= very small…5=very big				
	No	**Yes**		**1**	**2**	**3**	**4**	**5**
Do you think it is easy to influence your working hours?	67.2%	29.3%	If no:	4.7%	5.1%	18.8%	15.7%	33.7%
Do your working hours allow you to have a good work/ life balance?	80.2%	17.7%	If no:	1.4%	2.4%	8.4%	15.2%	53.6%
Do you think you get enough breaks at work?	64.7%	33.2%	If no:	2.4%	4.6%	14.4%	16.2%	44.5%

10. Are you able to swap shifts with other drivers?

☐ No – 7.5%

☐ Yes, with employer permission – 63.9%

☐ Yes, either with or without employer permission – 27.9%

a. If so, how often does this occur?

☐ Every month – 36.8%
☐ Every 2-3 months – 19.5%
☐ Every 4-6 months – 7.7%
☐ Once or twice a year – 25.6%

11. Thinking about your commute, which of the following do you use to get to work?

☐ Walk – 24.5% ☐ Car – 62.5% ☐ Train – 8.4%
☐ Bus – 37.2% ☐ Underground – 12% ☐ Cycle – 10.6%
☐ Other – 6.7%

a. During your commute, how long does it take you to get to work from home?

5 – 210 minutes (M = 39.49 minutes, SD = 25.11 minutes)

Questions about your sleep

12. In general, how would you rate your sleep in the last 3 months?

☐ Very good – 4.8%
☐ Quite good – 13.3%
☐ Neither good nor bad – 35%
☐ Quite bad – 34.6%
☐ Very bad - 11.9 %

13. Have you ever been diagnosed with a disorder or condition which affects your sleep, e.g. obstructive sleep apnoea?

☐ Yes – 4.4%
☐ No – 95.1%

a. Have you declared this to your employer?

☐ Yes – 69.5%
☐ No – 30.5%

14. Please indicate the degree to which the following have happened to you during the last 3 months.

	Never	Seldom *(One or few times a year)*	Sometimes *(Several times a month)*	Often *(1-2 times a week)*	Most often *(3-4 times a week)*	Always *(5 times or more a week)*
Difficulty in falling asleep	17.7%	15.4%	23.7%	15.3%	17.1%	8.3%
Difficulty in waking up	24.2%	19.7%	19.1%	13.1%	11.5%	9.7%
Repeated waking up during the night with problems falling asleep again	14.7%	17.2%	21.3%	14.8%	15%	14.3%
Severe snoring (own)	31.3%	15.9%	14.2%	8.5%	8.1%	18.3%

Difficulty catching your breath during sleep	70.6%	11.1%	5.6%	2.7%	2.2%	3.8%
Interrupted breathing during sleep (sleep apnoea)	78.2%	7.2%	4.2%	1.9%	1.5%	2.9%
Nightmares	44.5%	25.6%	13.1%	6.8%	3.0%	3.4%
Not feeling rested upon waking up	9.5%	14.9%	21.9%	17.4%	16%	17.8%
Waking up too early	11.5%	15.6%	23.7%	17.5%	14.3%	14.6%
Disturbed or worried sleep	17.4%	19.2%	20.3%	15.4%	11.2%	13.4%
Involuntary tremors in the legs that interfere with sleep	61.3%	13%	8.7%	5.1%	3.5%	4.9%
Overly light sleep	31.2%	20.6%	19.4%	10.4%	5.6%	8.8%
Being constantly tired throughout the day	12.5%	18.7%	22%	15.4%	12.3%	16.3%
Physical tiredness	12.9%	20%	22.5%	14.3%	12.7%	14.9%
Mental fatigue	14.3%	16.9%	19.3%	15%	13%	17.7%
Feeling sleepy at work	12.4%	18.5%	21.4%	18.6%	13.2%	13.2%
Feeling sleepy during leisure time	14.4%	17.8%	23.9%	16.4%	12.2%	11.8%
Involuntary falling asleep (e.g. microsleep) at work	50.7%	17%	12.2%	6.2%	4.9%	5.8%
Involuntary falling asleep (e.g. microsleep) during leisure time	40%	19.2%	13.8%	10.5%	6.7%	6.2%
The need to fight to stay awake during daytime	24.9%	22.5%	19.6%	10.5%	10.1%	10.1%

Sleep quality index – Range 1-6 (M = 3.35, SD = 1.36)
Sleepiness index – Range 1-6 (M = 2.83, SD = 1.31)
Fatigue index – Range 1-6 (M = 3.45, SD = 1.53)
Impaired Waking index – Range 1-6 (M = 3.34, SD = 1.45)
Suspected sleep apnea index – Range 1-6 (M = 2.03, SD = 1.18)

15. How much sleep do you ideally need between shifts to be able to drive safely/ feel rested?
Range = 5 – 11 hours (*M* = 7h, 55m, *SD* = 1h 8m).
NB. Answers from 10 participants were extreme outliers and have been excluded.

16. How much sleep do you usually get between shifts?
Range = 4 – 12 hours (*M* = 6h 30m, *SD* = 1h 20m)
NB. Answers from 13 participants were extreme outliers and have been excluded.

17. How often do you take a nap (a short sleep during the day)?

☐ Almost never – 44.3%
☐ A few times a month – 22.5%
☐ Once a week – 7.1%
☐ A few times a week – 17.5%
☐ Every day/ almost always – 7.8%

a. If you nap, on average how long do you nap for?
5-295 minutes (M = 61.80 minutes, SD = 45.74 minutes)

18. How many cups of coffee do you drink on average in a work day? (e.g. 0, 1, 2 etc.)
0 – 20 cups (M = 3.36, SD = 2.45)

19. How many cans of energy drink (e.g. redbull, monster) do you drink on average in a work day? (e.g. 0, 1, 2 etc.)
0 – 11 cans (M = 0.51, SD = 1.17)

20. Do you ever take caffeine tablets (e.g. ProPlus) on a work day?

☐ Never – 89.5%
☐ A few times a month – 6.4%
☐ At least once a week – 1.4%
☐ A few times a week – 1.6%
☐ Everyday/ almost always – 0.9%

Questions about your health

21. In general, how would you rate your health?

☐ Very good – 15.5%
☐ Quite good – 43.9%
☐ Neither good nor bad – 30.4%
☐ Quite bad – 9%
☐ Very bad 0.9%

22. On a scale from 1-10, where 1 is the lowest level, and 10 is the highest, how stressed would you rate yourself over the last 3 months?
Range 1- 10, mode = 8 (M = 5.67, SD = 2.81)

23. Are you a smoker?

☐ Non-smoker, never been a smoker, only smoked a few times – 49.4%
☐ Non-smoker, but previously have been a smoker – 22.8%
☐ Smoker – 22.2%
☐ E-cigarette user – 4.7%

24. How often do you exercise in your leisure time?

☐ Almost never, mostly inactive, occasional walks – 31.8%
☐ Seldom or irregular exercise, cycle or walk sometimes – 33.6%
☐ Regular, low impact exercise, cycle to work, walk often – 23.1%
☐ Regular, high impact exercise, at least twice per week – 9.4%
☐ Competitive exercise, training or competing – 1.6%

25. Do you take sleeping pills to help you sleep?

☐ No – 91.9%
☐ Yes, sometimes – 6.7%
☐ Yes, on a regular basis – 1%

26. Please read each statement and answer corresponding to how you have been feeling on average during the last 3 months

	Not at all	Sometimes	Quite often	Almost always
There are some days when I feel hyper all the time	60.4%	30.2%	6.4%	1.6%
There are days when I feel very stressed, at the limit of what I can handle	22.4%	42.4%	25.2%	9%
I have difficulties relaxing during leisure time	29.2%	39.5%	20.3%	9.8%
I am often tense	23.8%	39%	25.7%	10%
I often feel worried	19.4%	40.1%	27%	11.8%
I am often restless	20.8%	42.1%	24.5%	10.4%
I do not feel rested after being at home and resting for a couple of days	24.2%	34.4%	23.1%	16.8%
I have days when I feel stressed all the time	27%	36.1%	21.4%	13.7%

Questions relating to yourself as a bus driver

27. How much enjoyment do you get from bus driving? Please indicate on the scale below where 1 is no enjoyment (driving is for income only), and 10 is high enjoyment (driving is fun)

Range 1-10, mode = 1 (M = 4.95, SD = 3.01)

28. On a scale from 1-10, where 1 is the lowest level, and 10 is the highest, how stressed do you feel daily while driving the bus?

Range 1-10, mode = 3 (M = 5.45, SD = 2.79)

29. How often do you have to fight sleepiness in order to stay awake while driving the bus?

☐ Never – 21.4%
☐ Occasionally – 42.1%
☐ 2-4 times a month – 15.5%
☐ 2-3 times a week – 13.5%
☐ 4 or more times a week - 7.2%

30. In the past 12 months, have you had to stop the bus due to fatigue?

☐ Never – 76.9%
☐ Once – 8.9%
☐ Twice – 5.8%
☐ Three times – 1.3%
☐ More than three times – 6.6%

31. In the past 12 months, have you wanted to stop the bus due to fatigue, but been unable to?

☐ Never – 44.3%
☐ Once – 12.4%

☐ Twice – 11.4%
☐ Three times – 3.6%
☐ More than three times – 28.1%

32. In the past 12 months, have you fallen asleep whilst driving the bus?

☐ Never – 82.7%
☐ Once – 6.1%
☐ Twice – 2.7%
☐ Three times – 1.8%
☐ More than three times 6.1%

33. In the past 12 months have you have a 'close call' on the road while driving the bus because you were sleepy?

☐ Never – 63.3%
☐ Once – 15.7%
☐ Twice – 8.7%
☐ Three times – 2.6%
☐ More than three times – 9.5%

a. Do you think your employer knows that this close call was because you were sleepy?

☐ Yes – 11.7%
☐ No- 87.9%

34. In the past 12 months, have you had a road crash while driving the bus because you were sleepy?

☐ Never – 94.1%
☐ Once- 4.6%
☐ Twice – 0.7%
☐ Three times – 0.1%
☐ More than three times - 0.1%

a. Do you think your employer knows that this crash was because you were sleepy?

☐ Yes – 23%
☐ No – 77%

35. In the last 10 years have you experienced an incident or crash where sleepiness was partly or solely to blame? This could be whilst driving the bus, or whilst driving your own vehicle.

☐ No – 79.5%
☐ Yes, once – 13.1%
☐ Yes, several times – 3.7%
☐ Do not remember 3.2%

36. In the past 12 months when driving the bus, have you ever experienced any of these symptoms? Select all that apply

☐ Yawning – 88.7%
☐ Frequent eye blinks – 52.8%
☐ Difficulty keeping eyes open – 44.5%
☐ Difficulty in concentrating on driving – 40.6%

- ☐ Needing to change position frequently – 54.5%
- ☐ Slower reactions to traffic events – 33.4%
- ☐ Increased variation in speed – 15.7%
- ☐ Dreamlike state of consciousness – 35.3%
- ☐ Head nodding – 22.5%
- ☐ Other – 1.8%

37. What time of day are you most likely to feel sleepy whilst driving the bus? You can select more than one option.

- ☐ Early morning (04:00 – 08:00) – 42.1%
- ☐ Mid-morning (08:00 – 12:00) – 24.3%
- ☐ Afternoon (12:00 – 16:00) – 24.7%
- ☐ Early evening (16:00 – 20:00) – 14.6%
- ☐ Late evening (20:00 – 00:00) – 35.3%
- ☐ Night (00:00 – 04:00) – 29.1%
- ☐ I don't feel sleepy whilst driving the bus – 11.6%

38. At what point in your shift do you feel most sleepy whilst driving the bus? You can select more than one option.

- ☐ When you start driving – 17.2%
- ☐ Before a break – 28.9%
- ☐ After a break without food – 13.3%
- ☐ After a break with food/ lunch – 42.8%
- ☐ At the end of your shift – 38.1%
- ☐ Other – 4.1%
- ☐ I don't feel sleepy whilst driving the bus – 14.1%

39. At what point in your shift rotation do you feel most sleepy when driving the bus? You can select more than one option.

- ☐ First day back after a rest day – 28.3%
- ☐ Two days back after a rest day – 16.6%
- ☐ Last day of work before a rest day – 45.3%
- ☐ The first day of a new type of shift (e.g. the first early after a late) – 47.4%
- ☐ Other – 3.3%
- ☐ I don't feel sleepy whilst driving the bus – 14%

40. Do you do anything whilst driving the bus to reduce sleepiness and keep yourself alert? If so, what do you do? Select all that apply.

- ☐ Stopping for a break – 8.8%
- ☐ Opening a window – 85.9%
- ☐ Drinking caffeine – 34.2%
- ☐ Eating sweet or a sugary snack – 32.7%
- ☐ Chewing gum – 31.1%
- ☐ Singing/ talking to yourself – 35.2%
- ☐ Body movements whilst driving – 40.3%
- ☐ Exercise – 7.5%
- ☐ Music – 1.6%
- ☐ Turning on the fan or AC – 25.5%
- ☐ Driving slower – 17.2%

- ☐ Driving more actively – 12.1%
- ☐ Driving faster – 4.8%
- ☐ Make an excuse to stretch (e.g. check the mirrors or check the back safety window even though you know there is nothing wrong with it) – 29.4%
- ☐ Other – 3.9%
- ☐ I do not use any techniques to reduce sleepiness – 7.2%

41. Do you do anything when you are not driving the bus to reduce sleepiness and keep yourself alert (e.g. during breaks, between shifts, at bus stops)? If so, what do you do? Select all that apply.

- ☐ Going for a short walk – 46%
- ☐ Opening a window – 37.2%
- ☐ Drinking caffeine – 40.4%
- ☐ Eating sweet or a sugary snack – 21.3%
- ☐ Chewing gum – 16.1%
- ☐ Singing/ talking to yourself – 14.6%
- ☐ Exercise – 16.6%
- ☐ Music – 13.5%
- ☐ Turning on the fan or AC – 7.5%
- ☐ Make an excuse to stretch (e.g. check the mirrors or check the back safety window even though you know there is nothing wrong with it) – 16.3%
- ☐ Other - 5.9%
- ☐ I do not use any techniques to reduce sleepiness – 14.1%

42. How often do you have to actively do something to keep yourself alert when driving the bus?

- ☐ Never – 17.6%
- ☐ Occasionally – 44.3%
- ☐ 2-4 times a month – 12.4%
- ☐ 2-3 times a week – 14.1%
- ☐ 4 or more times a week – 10.9%

43. On a typical work day, do you bring your own food or buy something during the day?

- ☐ Bring my own food – 49.8%
- ☐ Buy something from my employers' canteen – 9.3%
- ☐ Buy food from a shop or café – 37%
- ☐ I don't have food at work – 3.5%

a. If you eat a meal during your work day, which of the following would you usually eat?

- ☐ Packet food/ meal deal (e.g. a packet sandwich with a snack and a drink) – 47.7%
- ☐ A small hot meal (e.g. a jacket potato) – 26.9%
- ☐ A large hot meal (e.g. meat and vegetables) – 18.6%

44. Do you encounter any of these difficulties during your scheduled rest periods?

				How big a problem is this for you? 1=very small…5=very big				
	Yes	*No*		*1*	*2*	*3*	*4*	*5*
Nowhere to sit	34.1%	59.5%	*If yes:*	4.1%	6.9%	16%	21.2%	43.5%
Inability to access a toilet	43.7%	50%	*If yes:*	1.9%	5.9%	12.4%	14.2%	55.5%
Insufficient time to eat	59.5%	33.9%	*If yes:*	3%	7.1%	17.6%	17.5%	43.4%
Insufficient time to rest	66.9%	26.3%	*If yes:*	2.7%	6%	18.1%	18.7%	42.9%
Late running of the bus leading to a shorter break	87.4%	9.8%	*If yes:*	4.1%	5.2%	13.3%	15.8%	49.7%
No access to an indoor rest area	37.4%	56%	*If yes:*	4.5%	5.3%	10.3%	11.9%	52.2%

Background Questions

45. What is your age?
Range 20 – 73 (M = 45.13, SD = 10.89)

46. What is your gender?
☐ Male – 85.7% ☐ Female – 10.6% ☐ Other – 0.2% ☐ Prefer not to say – 3.5%

47. What is your height? / 48. What is your weight?
BMI range 14.79 – 56.98 (M = 27.67, SD = 5.15)

49. What is your current relationship status?
☐ Single – 18.1%
☐ Living with a partner – 16.3%
☐ Married/ Civil partnership – 53.7%
☐ Separated/ Divorced – 5.8%
☐ Widowed – 0.3%
☐ Prefer not to say – 5%

50. Do you have children who live with you at home?
☐ Yes – 53.6%
☐ No – 45.4%

52. What is your highest level of education?
☐ No schooling completed – 4.1%
☐ Secondary school – 34.4%
☐ Sixth form or college – 26.4%
☐ Trade/ technical/ vocational training – 20.5%
☐ Bachelor's degree – 11.6%
☐ Master's degree – 1.6%
☐ Doctorate degree – 0.1%

Appendix J: Driver survey - univariate logistic regressions for having to fight to stay awake, and having a sleep related incident. OR = odds ratio, CI = confidence intervals, p = significance. Significant values are presented in bold.

	Have to fight sleepiness			Sleep related incident in the last 10 years		
Univariate variables	***OR***	***CI***	***p***	***OR***	***CI***	***p***
Sleep						
Sleep condition	**3.05**	**1.78-5.22**	**0.000**	1.42	0.75-2.69	0.28
Sleep quality	**2.06**	**1.83-2.31**	**0.000**	**1.45**	**1.30-1.61**	**0.000**
Sleepiness	**3.07**	**2.68-3.53**	**0.000**	**1.52**	**1.36-1.69**	**0.000**
Fatigue	**2.35**	**2.10-2.64**	**0.000**	**1.48**	**1.34-1.64**	**0.000**
Impaired waking	**2.38**	**2.12-2.68**	**0.000**	**1.43**	**1.29-1.59**	**0.000**
Sleep apnoea	**1.48**	**1.33-1.64**	**0.000**	**1.23**	**1.10-1.38**	**0.000**
Self-reported sleep quality: Bad (ref)						
Neutral	**0.11**	**0.06-0.20**	**0.000**	**0.30**	**0.19-0.50**	**0.000**
Good	**0.20**	**0.15-0.29**	**0.000**	**0.56**	**0.40-0.77**	**0.000**
Amount of sleep lost	**1.01**	**1.01-1.01**	**0.000**	**1.00**	**1.00-1.01**	**0.03**
Under sleeping: no (ref) vs yes	**3.09**	**2.10-4.55**	**0.000**	**2.05**	**1.40-3.00**	**0.000**
Snoring: no (ref) vs yes	**1.85**	**1.41-2.43**	**0.000**	**1.48**	**1.11-1.99**	**0.01**
Work						
Roster type: fixed (ref) vs rotating	1.15	0.88-1.50	0.30	**1.40**	**1.05-1.88**	**0.02**
Morning shift	1.35	0.90-2.03	0.15	1.38	0.88-2.16	0.17
Daytime shift	1.17	0.77-1.79	0.46	0.98	0.63-1.54	0.94
Evening shift	1.10	0.79-1.52	0.58	0.94	0.67-1.33	0.72
Night shift	0.88	0.62-1.24	0.46	0.84	0.57-1.24	0.38
Rota with day and evening shifts	1.29	0.94-1.77	0.11	1.27	0.90-1.78	0.17
Spreadover	1.15	0.85-1.57	0.36	1.27	0.90-1.78	0.17
Less than 11h break	**1.45**	**1.09-1.93**	**0.01**	1.15	0.85-1.56	0.38
6 or more days without rest	**1.82**	**1.16-2.84**	**0.01**	1.39	0.89-2.16	0.15
More than 10h overtime	1.13	0.86-1.50	0.39	1.18	0.87-1.60	0.28
Short notice of shifts	**1.62**	**1.22-2.14**	**0.001**	1.31	0.97-1.78	0.08
Variability in start times	**1.79**	**1.24-2.56**	**0.002**	**1.52**	**1.04-2.22**	**0.03**
Over running of routes	1.21	0.75-1.94	0.44	1.25	0.75-2.08	0.40
Enjoyment from bus driving	**0.84**	**0.80-0.88**	**0.000**	**0.88**	**0.83-0.92**	**0.000**
Stress from bus driving	**1.28**	**1.21-1.34**	**0.000**	**1.17**	**1.11-1.23**	**0.000**
Driving a car to work	1.04	0.79-1.36	0.78	1.02	0.76-1.37	0.89
Commuting using public transport	**0.74**	**0.57-0.98**	**0.03**	1.10	0.83-1.47	0.51
Commute time	**1.01**	**1.00-1.01**	**0.02**	1.00	1.00-1.01	0.10
Nowhere to sit during breaks	**1.65**	**1.26-2.17**	**0.000**	1.28	0.95-1.73	0.11
Insufficient time to eat during breaks	**1.98**	**1.46-2.69**	**0.000**	**1.42**	**1.03-1.96**	**0.03**
Insufficient time to rest during breaks	**2.68**	**1.86-3.86**	**0.000**	**2.44**	**1.65-3.63**	**0.000**
Late running of buses	1.45	0.89-2.37	0.13	**3.45**	**1.66-7.16**	**0.001**
No indoor rest area	**1.39**	**1.06-1.83**	**0.02**	1.18	0.88-1.60	0.27
Working hours per week	1.01	0.99-1.03	0.26	**1.02**	**1.00-1.04**	**0.02**
Health						
Self-reported health: Good (ref)						
Neutral	**1.82**	**1.36-2.44**	**0.000**	**1.82**	**1.33-2.49**	**0.000**
Bad	**3.30**	**2.22-4.90**	**0.000**	**2.46**	**1.59-3.83**	**0.000**
Stress in the last 3 months	**1.30**	**1.23-1.37**	**0.000**			
Smoker status: non-smoker (ref) vs smoker	**1.42**	**1.05-1.93**	**0.02**	1.04	0.74-1.47	0.81
Exercise: no (ref)						
No vs Low	0.89	0.64-1.24	0.50	0.91	0.64-1.29	0.59
No vs Reg	0.85	0.59-1.23	0.39	0.91	0.61-1.33	0.61
No vs Comp	1.39	0.91-2.13	0.13	0.75	0.45-1.27	0.29
BMI	1.00	0.98-1.03	0.83	1.00	0.98-1.03	0.81
Age: 20-29 (ref)						

30-39	0.77	0.48-1.24	0.28	1.29	0.72-2.31	0.39
40-49	**0.53**	**0.32-0.86**	**0.01**	0.94	0.52-1.71	0.84
50-59	**0.45**	**0.28-0.74**	**0.001**	1.02	0.57-1.83	0.95
60-73	**0.38**	**0.20-0.72**	**0.003**	0.79	0.38-1.66	0.53
Gender: male vs female (ref)	0.95	0.62-1.45	0.81	1.11	0.69-1.78	0.66
Multiple deprivation index	1.00	1.00-1.00	0.33	1.00	1.00-1.00	0.86

Multivariate logistic regressions were conducted using the forward stepwise method. The tables below show the final variables which emerged as significant predictors in the model.

Significant predictors in the multivariate logistic regressions for having to fight to stay awake. OR = odds ratio, CI = confidence intervals, p = significance.

	OR	***CI***	***p***
Sleepiness	2.38	1.92-2.94	0.000
Impaired waking	1.34	1.10-1.64	0.004
Enjoyment from bus driving	0.92	0.86-0.99	0.034
Commuting using public transport	0.58	0.38-0.90	0.014
Self-reported sleep quality: good (ref)			
Neutral	0.36	0.14-0.92	0.033

Note: R^2 = .28, Classification rate = 80.3%

Significant predictors in the multivariate logistic regressions for having a sleep related incident in the last 10 years. OR = odds ratio, CI = confidence intervals, p = significance.

	OR	***CI***	***p***
Fatigue	1.23	1.07-1.41	0.003
Enjoyment from bus driving	0.89	0.83-0.95	0.001

Note: R^2 = .04, Classification rate = 79.2%

Appendix K: GLM ANOVA. Fixed factors: Condition (morning vs Daytime); Time on task (5-10-15-20-25-30-35-40-45); Direction toward or from city. Main effects and interactions. Significant results in bold.

	Condition (morning vs daytime)		**Time on task** (5 min intervals)		**City** (from vs towards the city)		Condition*time on task		Condition*city		Time on task*city		**Participant**	
	F	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***
KSS (mean)	10.09	**0.002**	0.95	0.478	12.91	**0.000**	0.36	0.939	8.34	**0.004**	0.42	0.090	7.60	**<0.01**
Blinkduration (seconds)	7.08	**0.009**	0.74	0.660	0.07	0.788	1.43	0.189	0.05	0.825	0.43	0.899	32.00	**<0.01**
Long blinkdurations >0.15 s (%)	0.41	0.840	1.96	0.055	0.75	0.387	0.62	0.763	3.27	0.072	0.78	0.620	67.92	**<0.01**
SUS (mean)	13.02	0.000	1.10	0.366	0.17	0.677	0.69	0.699	0.33	0.070	0.62	0.760	16.96	**<0.01**
HRV RMSSD	44.79	**0.000**	1.73	0.095	11.17	**0.001**	1.42	0.193	21.76	**0.000**	1.34	0.230	33.48	**<0.01**
Speed (mph)	47.62	**0.000**	2.19	**0.032**	0.003	0.956	3.13	**0.003**	1.89	0.171	4.45	**0.000**	1.76	0.062
Accelerations (m/s2)	5.99	**0.016**	0.53	0.830	10.37	**0.002**	3.75	**0.001**	0.70	0.401	3.02	**0.004**	5.71	**<0.01**
Decelerations (m/s2)	1.70	0.194	0.92	0.499	4.25	**0.041**	2.49	**0.015**	1.31	0.255	1.92	0.061	6.56	**<0.01**

Appendix L: Summary of the research tasks which influenced each of the proposed solutions.

		Literature review or expertise	Policy review	Focus groups	Manager interviews	Survey	On-road study
Education	**Education relating to sleep and lifestyle**	✓	✓	✓	✓	✓	✓
	Driver responsibility to prioritise sleep and ensure they are well rested prior to duty				✓		✓
Working conditions	**Provide and ensure regular evaluation of suitable facilities for drivers to eat and rest**	✓	✓	✓	✓	✓	
	Improved access to facilities to enable healthy eating	✓	✓	✓	✓		
	Maintain buses to ensure they are always kept in a suitable condition	✓		✓			
Schedules	**Include fatigue risk assessment and mitigation in scheduling and rostering**	✓	✓	✓	✓	✓	✓
	Having safety and fatigue as a main consideration when designing schedules	✓			✓		
	Reducing the variability in shift start times	✓		✓	✓	✓	
	Using forward shift rotations	✓		✓			
	Allowing at least 11 hours between shifts	✓	✓	✓	✓	✓	
	Increasing the number of breaks per duty	✓				✓	
	Avoid having more than three consecutive early shifts	✓					✓
	Avoiding spread-overs	✓		✓			
	Openness to biomathematical modelling	✓					
	Protecting break and rest times	✓	✓	✓	✓	✓	
	Ensure that schedules are better matched with actual running time, at all times of day	✓		✓		✓	
	Providing more flexibility regarding drivers shifts			✓	✓		
	Considering the chronotype of the driver	✓					
Open Culture	**Fatigue risk management**	✓	✓	✓	✓		
	Moving away from a system which is only designed to deal with discipline			✓	✓	✓	
	Increasing the ability to report near misses due to fatigue			✓	✓	✓	

	Improving the relationship between drivers, managers, and traffic controllers			✓	✓		
	Openness to new technology	✓	✓	✓			
	The formation of a fatigue working group, including input from drivers	✓		✓			
Health	**Reducing stress and workload pressure whilst driving the bus**	✓		✓		✓	✓
	Improving the general health of drivers		✓		✓	✓	
	Providing health screening	✓				✓	
	Training for medical practitioners	✓					
	Tracking sleep health				✓		✓