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Fatigue Risk Management Systems: A Review of the Literature

Carina Fourie, Alexandra Holmes, Samira Bourgeois-Bougrine,
Cassie Hilditch and Paul Jackson
Clockwork Research Ltd

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Department for Transport
Great Minster House
76 Marsham Street
London SW1P 4DR
Telephone 0300 330 3000
Web site www.dft.gov.uk/pgr/roadsafety/research/rsrr

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CONTENTS

GLOSSARY

AETR	European Agreement concerning the Work of Crews of Vehicles engaged in International Road Transport
AFM	Advanced Fatigue Management – part of the new heavy vehicle driver fatigue regulations coming into force in Australia in September 2008
AIPA	Australian and International Pilots' Association
ALPA	Airline Pilots' Association
ATN	Australasian Transport News
ATSB	Australian Transport Safety Bureau
BAC	Blood alcohol concentration
BBC	British Broadcasting Corporation
BFM	Basic Fatigue Management – part of the new heavy vehicle driver fatigue regulations that came into force in Australia in September 2008
CAA	Civil Aviation Authority (United Kingdom)
CAA NZ	Civil Aviation Authority of New Zealand
CAO 48	Civil Aviation Order 48 – the flight and duty time limitations for the aviation industry in Australia specified by the regulator, CASA
CAP 371	Civil Aviation Publication 371 – the flight and duty time limitations for the aviation industry in the UK specified by the regulator, the CAA
CASA	Civil Aviation Safety Authority (Australia)
CEO	Chief Executive Officer
DERA	Defence Evaluation and Research Agency
EASA	European Aviation Safety Authority
EEA	European Economic Area
ERSO	European Road Safety Observatory
ETSC	European Transport and Safety Council
EU	European Union
FAA	Federal Aviation Administration (USA)
FAID	Fatigue Audit InterDyne – a fatigue modelling computer software programme
FDM	Flight Data Monitoring
FMP	Fatigue Management Programme
FRMS	Fatigue Risk Management System – an FRMS is a scientifically-based, data-driven addition or alternative to prescriptive hours of work limitations which manages employee fatigue in a flexible manner appropriate to the level of risk exposure and the nature of the operation
HGV	Heavy goods vehicle (same as large goods vehicle or LGV)
HOS	Hours of Service – the hours of work limitations for commercial vehicle drivers in the USA
HoW	Hours of work
HRSCCTA	House of Representative Standing Committee on Communications, Transport and the Arts (Australia)
HSE	Health and Safety Executive (UK)

ICAO	International Civil Aviation Organization
IPIECA	International Petroleum Industry Environmental Conservation Association
LGV	Large goods vehicle (same as HGV) – in the UK these are trucks weighing more than 3.5 tonnes
LTNZ	Land Transport New Zealand – formerly the LTSA, now known as the NZ Transport Agency
LTSA	Land Transport Safety Authority (New Zealand) – now known as the NZ Transport Agency
MCA	Maritime and Coastguard Agency (UK) – a subdivision of the Department for Transport responsible for implementing maritime safety policy
NCSR	National Center on Sleep Disorders Research
NHTSA	National Highway Traffic Safety Administration
NRTC	National Road Transport Commission (of Australia) – now the NTC
NTC	National Transport Commission (Australia)
NTSB	National Transportation Safety Board (USA)
NZ	New Zealand
OGP	International Association of Oil and Gas Producers
OH&S	Occupational Health and Safety
OSA	Obstructive sleep apnoea (also known as OSAHS – obstructive sleep apnoea/hypopnoea syndrome)
PCV	Passenger carrying vehicle
RCGB	*Road Casualties Great Britain* – the annual report produced by the UK Department for Transport Statistics Division, presenting statistics about reported personal injury road collisions and their consequent casualties
ROGS	Railways and Other Guided Transport Systems (Safety) Regulations 2006 (UK)
RoSPA	Royal Society for the Prevention of Accidents
RTC	Road traffic collision – this term replaces the commonly used 'road traffic accident' and includes incidents where only one car was involved
SAFE	System for Aircrew Fatigue Evaluation – a fatigue modelling software programme
SMS	Safety Management Systems
Transport Canada	Transport regulator for Canada
VOSA	Vehicle and Operator Services Agency

EXECUTIVE SUMMARY

Introduction

Work-related road safety is one of the key areas of concern for the UK Department for Transport and driver fatigue is a particularly prevalent cause of work-related road traffic collisions (RTCs) resulting in injury or death. As part of the Department for Transport's continuing efforts to improve work-related road safety, Clockwork Research has been commissioned to research Fatigue Risk Management Systems (FRMS), a relatively new and potentially advantageous method for managing the risk posed by commercial driver fatigue. An FRMS is a Safety Management System (SMS), or part of an SMS, which manages fatigue in a comprehensive and systematic manner using formal risk-based processes.

The first part of the project, reported in this publication, constitutes a review of the academic papers and other relevant literature available on FRMS, including industry reports and regulatory guidance. Part two of the project, reported separately, will involve interviewing regulators, operators and researchers with experience of FRMS in order to learn firsthand about the advantages and disadvantages of FRMS.

The problem of fatigue: causes, effects and the road transport industry

Fatigue can be defined as a combination of symptoms: 'impaired performance (loss of attentiveness, slower reaction times, impaired judgement, poorer performance on skilled control tasks and increased probability of falling asleep) and subjective feelings of drowsiness or tiredness' (NRTC, 2001: 21). If experienced behind the wheel, the impaired performance associated with fatigue can result in an RTC. An analysis of UK road casualty data concluded that 17% of RTCs occurring on major trunk roads which resulted in injury or death were sleep-related (Flatley *et al.*, 2004).

Fatigue-related collisions are particularly prevalent among commercial vehicle drivers because of the extended amount of time they spend on the road, the long hours that are worked and shifts that start at various times of the day and night. The need to manage the fatigue risk posed by commercial drivers is also pressing because RTCs which involve large goods vehicles (LGVs) are much more likely to cause injury and death than RTCs involving most other types of vehicles (Department for Transport, 2001).

The prescriptive approach to fatigue management

The conventional approach to managing work-related fatigue involves hours of work (HoW) limitations: organisations comply with prescriptive regulations which determine, for example, the maximum duration of a working day and the minimum duration of time off. An example in the road transport industry is the European Union's Drivers' Hours Rules and Regulations for Large Goods Vehicle (LGV) Drivers.

HoW limits are valuable in that they provide unambiguous upper limits within which organisations must work. However, prescriptive limits are increasingly being criticised for being an overly simple solution to a complex problem. By their nature, prescriptive limits take a 'one size fits all' approach that does not consider the different conditions in which operators work or the risks that are encountered. In addition, HoW limits only consider work-related fatigue and are rarely defensible from a scientific perspective.

A small number of proactive operators use additional strategies, such as fatigue management training and education for drivers, to enhance the extent to which the operation is protected from fatigue risk. However, as these strategies are not usually integrated into a broader management system, they tend to be used sporadically and their benefits are not always realised.

What is a Fatigue Risk Management System?

An FRMS is defined as a scientifically-based, data-driven addition or alternative to prescriptive HoW limitations which manages employee fatigue in a flexible manner appropriate to the level of risk exposure and the nature of the operation (Brown, 2006; ALPA, 2008).

FRMS originated in Australia and New Zealand in the 1990s in the context of broader developments in outcome-based regulations and SMS. Outcome-based regulations are usually associated with risk management: rather than simply applying prescribed controls, for example HoW limits, organisations assess their risk and determine what controls are actually appropriate to achieving an outcome, for example an acceptable level of safety. An SMS is a business-like approach to safety which recognises that an acceptable level of safety is the result of successful management techniques. It is an organised approach with set goals, levels of authority, policies and procedures and clear accountabilities for operational safety (ICAO, 2008). Essentially, FRMS emerged when regulators and operators, concerned about the losses associated with fatigue, recognised that fatigue is 'just another risk' that can be managed using an outcome-based regulation and a systematic risk management approach.

As with SMS, for an FRMS to be effective it needs to be supported by a just safety culture in which there is open and honest reporting of safety issues within the organisation. There also need to be clear lines of accountability for the management of fatigue risk and integration between an organisation's FRMS and SMS. An FRMS is often described as consisting of six core components, although the precise content of an FRMS should be flexible to an organisation's needs:

- a company fatigue management policy;
- fatigue risk management procedures;
- a process for employees to report fatigue to management;
- a process for investigating the potential role fatigue plays in incidents;
- fatigue management training and education for employees and management; and
- a process for the internal and external auditing of the FRMS.

The purported advantages of FRMS for managing fatigue, compared with HoW limits and other isolated strategies, are that:

- FRMS is data-driven, it measures actual risks and develops tailored controls;
- multiple causes of fatigue and defences against fatigue are considered;
- FRMS can enhance operational flexibility;
- responsibility for managing the risk of fatigue rests with operators;
- FRMS is a systematic and documented approach to fatigue management; and
- FRMS involves proactive and reactive risk management.

The evolution and evaluation of Fatigue Risk Management Systems

To date, four road transport and aviation regulators have initiated industry trials of FRMS which have been formally evaluated and published. The evaluations primarily collected subjective data from managers and employees via surveys and interviews:

- **Queensland Fatigue Management Programme (FMP) trial:**
  - Initiated in conjunction with road transport operators in Queensland, Australia in 1994.
  - Positive results overall, for example, reduced driver fatigue and enhanced flexibility in scheduling were reported.
- **Civil Aviation Authority (CAA NZ) of New Zealand scheme:**
  - Since 1995, an alternative compliance scheme has enabled operators who develop an FRMS to work outside the prescriptive HoW limits.
  - The evaluation found that operators who were supposed to have an FRMS in place were largely still relying on the prescriptive limits.
- **Land Transport Safety Authority (LTSA) of New Zealand trial:**
  - In 2000 the regulator initiated a trial of FRMS for road transport. The trial

was not completed due to a change in regulation.
  - Trial design highlighted the problem of driver attrition for data collection and evaluations of FRMS.

- **The Civil Aviation Safety Authority (CASA) of Australia trial**
  - In 2001, general aviation operators commenced a trial of FRMS.
  - The majority of participating companies agreed that the FRMS had a positive impact on operations. However, problems in the implementation of FRMS included a lack of risk assessment and the misuse of fatigue modelling software.

Overall, the results of the evaluations were supportive of FRMS. The primary reported advantages of FRMS were an increased awareness and understanding of fatigue, enhanced safety, and increased operational flexibility. The reported disadvantages associated with FRMS are largely typical of any significant operational change, for example the difficulty of gaining employee understanding and commitment. Challenges specific to fatigue management were also identified, such as over-reliance on fatigue modelling software.

The trials provide considerable useful information on how to avoid the difficulties that have been encountered in the past for regulators considering introducing FRMS to industry. A notable weakness with all of the trials was the lack of an explicit requirement for operators to undertake and maintain a risk management process. It is therefore recommended that detailed and easy-to-understand information and guidance on FRMS is provided to operators, with a focus on risk management. It is also recommended that future evaluations of FRMS aim to collect objective data to quantify the benefits of FRMS for safety.

Recent regulatory developments in Fatigue Risk Management Systems

Since the evaluation of the FRMS trials, new regulations relating to FRMS in the transport industries have been developed. Most notably, the results of the Queensland FMP trial have contributed to the development of new legislation and guidelines for fatigue management in road transport in Australia.

The new regulations emphasise that all operators have a duty to manage their employees' fatigue, consistent with health and safety legislation. Additionally, chain of responsibility legislation determines that managing fatigue is a responsibility of all parties in the supply chain, not solely the responsibility of the driver and the operating company. In terms of HoW rules, the reform offers operators three options: Standard Hours, Basic Fatigue Management (BFM) and Advanced Fatigue Management (AFM). Standard Hours are the 'default' HoW. Operators who require greater flexibility need to develop an accredited BFM or AFM scheme, which is effectively an FRMS.

Outside of Australia and New Zealand, FRMS has received the most attention from Europe and North America. The European Aviation Safety Authority (EASA) has formally suggested that FRMS should be a requirement for all aviation operators in the coming years and the UK rail regulator has made having an SMS, including a requirement to manage fatigue, compulsory for operators. In North America, Transport Canada has made available detailed guidelines for the development of FRMS in aviation and the maritime industry. The National Transportation Safety Board (NTSB) has recommended that the US Federal Aviation Authority (FAA) develop guidance for operators to establish scientifically-based FRMS and to design a methodology to establish the effectiveness of these systems.

Summary and next steps

In conclusion, there is clearly a need to improve the management of commercial driver fatigue risk and relying on HoW limitations is increasingly being perceived as an overly simplistic strategy. In theory, a risk-based and systematic approach to fatigue management is more effective and the trials of FRMS that have been conducted have provided encouraging, albeit mainly subjective, results.

The next stage in the project will involve interviewing regulators, operators and other relevant groups with experience of FRMS in order to collect candid information on how FRMS has fared in practice; how best to realise the potential benefits for safety of FRMS; and how to avoid problems with its implementation.

As FRMS is a relatively recent approach and there are a small number of organisations with FRMS experience, a world-wide search for people to interview will be necessary, and individuals from the road transport, aviation, rail and maritime industries will be approached.

The results of the literature review and the interviews will inform a comprehensive set of recommendations for the Department for Transport on how to progress with regards to FRMS as a potential strategy for managing the fatigue risk associated with commercial vehicle operations in the UK.

1 INTRODUCTION

1.1 Background

Drivers who are on the roads for work-related reasons, such as professional lorry drivers and company car drivers (referred to hereon as commercial drivers), are estimated to be involved in 25–33% of all fatal and serious crashes on British roads (Work-related Road Safety Task Group, 2001). Consequently, work-related road safety is one of the key areas of concern for the UK Department for Transport and a range of initiatives to tackle the problem are underway. One of the main causes of road traffic collisions (RTCs) among commercial drivers is fatigue, which is perhaps not surprising considering that these drivers are on the road for considerable periods of time and often involved in shift work.

Driver fatigue is an especially pressing road safety concern because fatigue-related RTCs are more likely to result in death or serious injury than collisions caused by other factors (Department for Transport, 2001). The key reason for this is that extremely fatigued drivers can fall asleep unintentionally behind the wheel, sometimes at high speed, and in this state they cannot brake or take evasive action when faced with a hazard. Where the driver is operating a large goods vehicle (LGV), the size and weight of the vehicle increases the severity of the damage to other road users.

The conventional approach for managing employee fatigue, including commercial fatigue, is via compliance with the prescriptive regulations regarding the maximum number of hours that can be worked and the minimum amount of rest/non-work time that an employer must provide. Examples of these regulations, collectively known as 'hours of work (HoW) limitations', include the European Union's Drivers' Hours Rules and Regulations for Large Goods Vehicle (LGV) drivers. While HoW limitations are easy to understand and are largely consistent across the EU, they have been criticised by the scientific community for failing to adequately control the number of fatigue-related accidents occurring.

Chief among the criticisms is the fact that HoW limitations are a 'one size fits all' approach to managing a complex problem. In isolation, a set of simple limits on work and rest hours cannot take into account the impact on fatigue of operational factors such as differences in workload (e.g. the number of times a driver has to unload per shift), working conditions (e.g. driving in fine conditions versus icy conditions), and personal factors, such as age, health, and domestic and social activities. Another determinant of fatigue that is largely ignored by HoW limitations is the influence of the body clock; a cluster of cells in the brain which insists that alertness is greatest during the day and reaches a minimum at night. Moreover, it is argued that in the presence of a mandatory set of HoW limitations, operators are not inclined to actually address how different variables are influencing the level of fatigue encountered by their drivers or the level of fatigue risk associated with the operation. Without data relating to the impact that fatigue has on health, safety and productivity, fatigue risk cannot be managed in an informed manner.

In recognition of the limitations of prescriptive approaches to managing work-related fatigue, a more comprehensive approach, known as Fatigue Risk Management (FRM), has evolved. FRM originated in Australia and New Zealand, and is an outcome-based approach that involves measuring the level of fatigue risk associated with an operation and applying the appropriate countermeasures or controls. For example, typical FRM controls could include altering the timing of shifts, educating drivers on the importance of obtaining adequate sleep and how to manage their fatigue, and the introduction of a system for drivers to report instances of fatigue. From the regulator's perspective, FRM shifts the focus from ensuring that companies are compliant with a set of rules to encouraging them to measure and manage the actual fatigue risk associated with their operation.

As fatigue is 'just another safety issue', the most comprehensive strategy for managing fatigue is to embed it within a Safety Management System (SMS). The components of the SMS that are involved in the management of fatigue are referred to as a Fatigue Risk Management System (FRMS). An FRMS can be defined as a scientifically-based, data-driven addition or alternative to prescriptive hours of work limitations which manages employee fatigue in a flexible manner appropriate to the level of risk exposure and the nature of the operation (Brown, 2006; ALPA, 2008).

In recognition of the pressing problem of commercial driver fatigue and the inadequate protection afforded by HoW limitations, the Department for Transport has commissioned Clockwork Research Ltd to research the literature and experiences of FRMS around the world, with a view to exploring whether FRMS has the potential to enhance the management of commercial driver fatigue in the UK.

1.2 Objectives

1.2.1 Research objectives

The research has three principal objectives:

1. To improve our understanding of the evolution of FRMS as an approach to managing fatigue.
2. To learn from the experiences of regulatory authorities and companies in countries that have implemented FRMS.
3. To provide the Department for Transport with recommendations on how FRMS could be adopted in the UK.

This report fulfils the first part of the research programme by providing a review of journal papers, industry reports and regulatory advice relating to FRMS. The other two objectives are met in a subsequent complementary report which will describe the outcome of surveys and interviews conducted with regulators, operators, researchers and other groups around the world who have experience of implementing an FRMS.

1.2.2 Literature review objectives

The broad purpose of the literature review is to describe and explain the evolution of FRMS. The review will describe the components of an FRMS and how these systems have been implemented in different countries. Below is a set of questions that it was deemed essential for the review to address specifically:

- Why is it necessary to manage the fatigue of commercial drivers?
- What methods have been used to manage the fatigue of commercial drivers?
- How successful have traditional methods, such as HoW limitations, been for managing fatigue?
- What is an FRMS?
- What are the key elements of an FRMS?
- What are the advantages of FRMS over other approaches to managing fatigue?
- What difficulties have been experienced where FRMS have been implemented?
- How effective have FRMS been at managing commercial driver fatigue?

Finally, the literature review will guide the next research task in two ways: first, by identifying regulators, operators, researchers and other groups who have implemented elements of an FRMS and who should be approached for survey and interview; and second, the conclusions of the review will be used to design suitable interview questions.

1.3 Literature sources

At the outset of the project the study team met to discuss the literature sources that should be searched and the search terms that should be used to explore these sources. Research for the literature review was conducted using the following library databases:

- Risk Abstracts;
- Transport;
- Medline;
- Psychinfo;
- OSH (Occupational Safety and Health); and

- the British Library Integrated Catalogue.

The search terms used with appropriate Boolean operators were: ‘fatigue*’, ‘tired*’, ‘alert*’ and ‘sleep*’ combined with each of the following segments of words ‘manag*’, ‘risk*’, ‘driv*’, ‘pilot*’, ‘aviation’, ‘road’; ‘rail’, ‘marine’, ‘maritime’ or ‘transport*’. The phrases ‘safety management system’ and ‘occupational road risk’ were also used to search the databases.

All the search terms were also used to search the websites of relevant departments for transport worldwide.

1.4 Structure of the report

This report consists of seven sections, including this introductory section:

- Section 2 provides an overview of the causes and consequences of fatigue and describes the risk that fatigue poses on the road.
- Section 3 discusses the effectiveness of HoW limitations and other fatigue management strategies for managing work-related fatigue.
- Section 4 introduces Fatigue Risk Management Systems (FRMS) and describes the benefits of an FRMS over HoW limitations and isolated strategies for managing fatigue.
- Section 5 reports on the results of previous assessments of FRMS. This section considers how effective they have been in practice, identifies problems associated with their implementation and provides suggestions for how these problems might be avoided in any future implementation.
- Section 6 discusses recent developments with regard to FRMS worldwide.
- Finally, Section 7 summarises the findings of the literature review and describes additional research required to establish comprehensive guidance on whether FRMS should be implemented and how it can be implemented effectively.

1.5 Scope of the report

This report seeks to explore the possibility that FRMS could improve the management of commercial driver fatigue. With this in mind, the different controls and countermeasures for fatigue that can be applied, such as company-specific HoW limitations, napping strategies and driver fatigue management training, are only considered in terms of their role within an FRMS. The report does not include a review of the multitude of different controls and countermeasures *per se*. As FRMS is applicable to commercial vehicle drivers, the report does not consider the different ways in which driver fatigue experienced by the general public could be addressed.

1.6 Acknowledgements

The authors would like to acknowledge the valuable contributions of the various regulatory authorities, authors of assessment reports and transport operators involved in trials of early examples of FRMS in Australia and New Zealand who were contacted and asked to provide feedback on the descriptions of the trials and their evaluations in Section 5. In particular, the authors would like to thank the following individuals for providing feedback on the report:

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2 THE PROBLEM OF FATIGUE: CAUSES, EFFECTS AND THE ROAD TRANSPORT INDUSTRY

2.1 Introduction

Over the past 20 years our awareness of the safety risk posed by human fatigue has been elevated by industrial disasters such as the Exxon Valdez oil spill, which has been, at least partially, attributed to fatigue (NTSB, 1990; Folkard and Lombardi, 2006). Similarly, the catastrophic consequences that can result from driver fatigue have been demonstrated by road and rail crashes, including the Selby rail crash (a.k.a. the Great Heck rail disaster). While such high profile events are undeniably tragic, they are fortunately rare. Yet research suggests that fatigue is responsible for hundreds of deaths and thousands of serious injuries on our roads every year: an analysis of UK road casualty data has concluded that 17% of road traffic collisions (RTCs) on major UK roads resulting in injury or death were sleep-related (Flatley *et al.*, 2004).

This section explores fatigue – its causes, its effects and why it is a problem on the roads:

- Section 2.2 defines fatigue;
- Section 2.3 discusses the causes of fatigue, and distinguishes between individual, environmental and work-related contributors;
- Section 2.4 considers the consequences of fatigue for the individual, the organisation and the community; and
- Section 2.5 considers fatigue on the roads, in particular commercial driver fatigue.

2.2 Definition of fatigue

The definition of fatigue used in this report was developed by a group of fatigue experts who convened in 2001 to advise the National Road Transport Commission (NRTC), and the Australian Government more broadly. Fatigue was defined in two statements that consider (1) the combination of symptoms that research has shown to be indicative of fatigue and (2) contributors to fatigue**:**

- Symptoms of fatigue: impaired performance (loss of attentiveness, slower reaction times, impaired judgement, poorer performance on skilled control tasks and increased probability of falling asleep) and subjective feelings of drowsiness or tiredness.

- Contributors to fatigue: long periods awake, inadequate amount or quality of sleep over an extended period, sustained mental or physical effort, disruption of circadian rhythms (the normal cycles of daytime activity and night sleep), inadequate rest breaks and environmental stresses (such as heat, noise and vibration).

(NRTC, 2001: 21)

By describing fatigue in terms of impaired performance, the NRTC definition assists us in appreciating fatigue as a safety issue. We understand that drugs and alcohol cause impairment and that it is unacceptable to drive when under the influence; from the definition it follows that it is also unacceptable to be on the road when impaired by fatigue. The definition includes both the symptoms of a mild level of fatigue, such as slower reaction times, and high levels of fatigue, for example falling asleep (unintentionally).

From a road safety perspective, recognition of the breadth of the impact that fatigue can have on performance is timely. Prior research has tended to define fatigue-related RTCs as incidents where a driver has fallen asleep at the wheel (e.g. Horne and Reyner, 1995). The NRTC definition encourages the consideration of instances where the driver was not asleep, but their performance was significantly impaired in other ways by fatigue. While many fatigue-related RTCs (particularly the most severe ones) are caused by drivers who have fallen asleep at the wheel, it is likely that many less severe collisions (as well as some of the most severe) are caused by drivers who may not be asleep, but who are suffering from less severe symptoms of fatigue-related impairment, such as increased ease of distraction, reduced vigilance or loss of attention (Dobbie, 2002).

The NTRC definition takes an inclusive approach to the causes of fatigue and identifies a wide variety of contributory factors, including sleep loss, effort and environmental conditions. Other, less inclusive definitions have described fatigue as 'the consequence of physical labor or a prolonged experience', or the result of mental or physical effort, as distinct from sleepiness which is 'the need to fall asleep' (NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness, 1998). The fact that the NRTC definition encompasses multiple contributors to fatigue further enhances its value to the road safety arena. Essentially, the definition draws a broad circle around many reasons we may feel fatigued and many of the ways in which our performance may consequently be impaired, thereby identifying fatigue as a road safety issue that clearly needs to be managed.

2.3 Causes of fatigue

The multiple causes of fatigue can be divided into three main categories:

1. individual or personal factors (e.g. age, domestic demands);
2. environmental factors (e.g. ambient temperature, noise levels); and
3. work-related factors (e.g. schedule design, extended work hours).

The majority of these factors promote fatigue by causing sleep loss, either by reducing sleep duration or extending hours of wakefulness, and/or disturbing the times that we are awake and asleep. Across 24 hours our body clock ensures that alertness varies in a predictable pattern to promote wakefulness during the day and sleep at night. When we sleep and wake at times that conflict with the body clock, for example because we are working a night shift, our alertness at work can be reduced and it can be difficult to obtain adequate sleep during the day. Before considering the various factors that can influence fatigue, this section first provides some basic information on sleep loss and the body clock.

2.3.1 Sleep loss

Over the past 40 years a number of studies (e.g. Wilkinson *et al.*, 1966; Taub and Berger, 1973; Carskadon and Dement 1981; Rosenthal *et al.*, 1993; Dinges *et al.*, 1997) have demonstrated that sleep loss results in increased subjective reports of sleepiness and impaired performance on objective measures of cognitive performance.

Single night sleep deprivation studies have consistently demonstrated that performance on vigilance tasks is one of the cognitive skills most readily affected by sleep loss. These studies have shown that the performance of vigilance tasks is significantly impaired when an individual's sleep has been restricted to five hours on the previous night (Wilkinson *et al.*, 1966; Taub and Berger, 1973).

While the majority of sleep research to date has focused on the effects of a single night of sleep loss or extended periods of wakefulness, more recently there has been increasing investigation of the consequences of partial sleep loss accumulation: when sleep loss occurs repeatedly over a number of consecutive nights, a relatively small amount of sleep loss per night can accumulate to cause a significant level of impairment.

Two important studies have used similar research designs to further explore the issue of cumulative fatigue. The first of these (Belenky *et al.*, 2003) involved restricting participants to three, five, seven or nine hours in bed over a period of seven days. The research showed that when 'time-in-bed' fell to five hours, performance on a vigilance task was significantly impaired after the third night. Van Dongen *et al.* (2003) employed a similar experimental design whereby participants were restricted to four, six or eight hours in bed, for a 14-day period. In this study the four-hour group showed significant declines in vigilance after two days. Those restricted to six hours in bed for the duration of the study were able to maintain performance until between days six and eight, but by the end of the study their performance had declined to levels approaching clinical significance. These findings are of particular relevance to the current study, as commercial vehicle drivers are more likely to experience cumulative fatigue, resulting from obtaining less sleep than required over successive nights, rather than going without sleep on one particular night.

Besides reduced vigilance, sleep loss is also associated with impaired memory (Van Dongen *et al.* 2003), negative mood (Dinges *et al.* 1997; Lieberman et al 2002), and increases in error rates (Neri *et al.*, 1992; Gander *et al.*, 2000).

2.3.2 *The body clock*

Fatigue is largely determined by the combined influence of the duration of sleep/wakefulness and the body clock (Åkerstedt, 1988; Van Dongen and Dinges, 2005). Consisting of a cluster of cells located in the brain's suprachiasmatic nucleus, the primary body clock (sometimes known as the circadian or biological clock) instructs many different systems in the body to promote alertness during the daylight hours and to encourage sleep during the night. In other words, it ensures that our body systems vary their activity levels to suit the 24-hour cycle in day and night.

The body clock generates rhythms known as 'circadian' rhythms (from the Latin words 'circa', meaning about, and 'dies', meaning day, or 24 hours). The circadian rhythm in sleep is the result of a pattern of increasing and decreasing sleepiness across a roughly 24-hour period (Zee and Turek, 1999), with the highest level of sleepiness occurring in the early morning between around 02:00 and 06:00 when the urge to sleep is the strongest (Åkerstedt, 1990; Folkard *et al.*, 2005). Consequently, fatigue-related RTCs are most likely to occur at night or in the early hours of the morning (Horne and Reyner, 1995). The lowest levels of sleepiness occur around mid-morning and in the evening between about 20:00 and 22:00 (Lavie, 1986; Åkerstedt, 1990). At these times, sleep is most difficult to obtain and maintain.

In the following sections the variety of individual, environmental and work-related factors that can influence fatigue are demonstrated using examples. For more detailed information on a given cause, the reader is directed to the references cited. For most of the factors, it will be apparent that fatigue occurs via sleep loss, extending hours of wakefulness, being awake at a time when the body clock is promoting sleepiness, or trying to obtain sleep when the body clock is promoting alertness. However, there are a smaller number of contributors – such as workload – that promote fatigue without necessarily interacting with sleep or the body clock.

2.3.3 *Individual factors that contribute to fatigue*

A wide range of individual factors can influence the amount of sleep that an individual is able to achieve and therefore contribute to fatigue. Some of the individual determinants of fatigue are physical characteristics, for example whether we have a tendency to feel more alert in the morning or the evening (chronotype) and age. As we age our susceptibility to sleep disturbances increases, while our ability to sleep at varied times and to cope with night shifts and jetlag diminishes (Moline *et al.*, 1992; Härmä, 1993; Gander *et al.*, 1993; Härmä *et al.*, 1994; Härmä, 1996).

2.3.3.1 Lifestyle

Other individual causes of fatigue are related to lifestyle, for example: whether an individual has a second job; commute duration; and child care responsibilities. All of these variables promote fatigue by reducing the time available for sleep. For shiftworkers, balancing social and domestic responsibilities with the need to obtain adequate sleep is particularly difficult as these demands may need to be met at the same time. For example, a shiftworker working shifts that commence at 05:00 might need to go to bed early in the evening in order to obtain sufficient sleep before commencing their shift, but may also have to attend to domestic responsibilities such as preparing dinner or caring for children in the evening, which interfere with their ability to go to sleep early.

2.3.3.2 Sleep disorders

The International Classification of Sleep Disorders lists over 80 disorders of sleep and wakefulness. The majority of these are extremely rare, but some – notably insomnia and obstructive sleep apnoea/hypopnoea syndrome (OSAHS) – are more common. Most adults will at some time experience a bout of temporary insomnia, while it has been estimated that approximately 1–2% of middle-aged men in the UK suffer from OSAHS (a sleep disorder characterised by repetitive collapses and re-openings of the upper airway during sleep (Stradling and Davies, 2004)), equating to around 300,000 people and giving the condition a similar prevalence to Type 1 diabetes (SIGN, 2003; Sleep Alliance, undated). OSAHS is of particular concern, as sufferers experience elevated levels of fatigue and have been shown to be 7–12 times more likely to have an RTC than those without the disorder (Findley *et al.*, 1988; SIGN, 2003). Furthermore, sleep-disordered breathing and OSAHS are thought to be prevalent among truck drivers (Howard *et al.*, 2004).

2.3.3.3 Drugs and alcohol

Prescription drugs, such as antidepressants, and over-the-counter medicines, such as cold and flu medications, can contribute to fatigue by disrupting sleep (Leveille *et al.*, 1994) or by causing significant drowsiness and daytime sedation, or both (Nicholson *et al.*, 1991; Horne and Barrett, 2001). Stimulant drugs such as caffeine and cocaine all interfere to varying degrees with an individual's ability to get to sleep and remain asleep, particularly when ingested within a few hours of bedtime (Roehrs and Roth, 2008; Pace-Schott *et al.*, 2005). Studies also show that even small amounts of alcohol can adversely impact on sleep quality and respiration during sleep (Landolt *et al.*, 1996; Vitiello, 2006).

2.3.4 Environmental factors that contribute to fatigue

The ideal sleep environment is cool, dark, quiet and comfortable, and when this is not the case sleep can be reduced. Noise that exceeds approximately 45 dB, continuous background noise and the number of noise events that occur during a sleep period make it difficult to fall asleep and disturb sleep quality (Ohrstrom *et al.*, 1988; Ohrstrom, 1995; Robertson *et al.*, 2000). Similarly, light (Robertson *et al.*, 2000) and high temperatures (Kronauer, 1994) have been shown to increase the number of awakenings during sleep. Compared with sleeping in a comfortable bed, sleeping in a truck or an armchair has an adverse impact on the quality and quantity of sleep that an individual is able to obtain (Nicholson and Stone, 1987; Pascoe *et al.*, 1994; 1995).

Creating a sleep environment that is conducive to sleep is particularly difficult for shiftworkers who have to obtain their sleep during the daytime when it is light and the environment is noisier, for example due to increased traffic.

2.3.5 *Work-related factors that contribute to fatigue*

2.3.5.1 Timing of work and timing of time off

As circadian rhythms promote sleep at night and wakefulness during the day (Åkerstedt, 1988; 1990), it is largely inevitable that those who have to work at night and have to obtain sleep during the day will be susceptible to fatigue. Sleeping during the day leads to shorter sleep duration and sleep of poorer quality than sleeping at night (Åkerstedt, 1990; 2003; Gander *et al.*, 1998; Roach *et al.* 2003).

Early morning duties have also been shown to be associated with sleep loss and fatigue (Folkard and Tucker, 2003). There are physiological and psychosocial explanations for the sleep loss that occurs on early duties. From a physiological perspective, it is difficult to go to sleep early enough in the evening in order to obtain enough sleep before the start of an early shift. The time period between around 20:00 and 22:00 is known as the ‘forbidden sleep zone’ because at this time because the circadian rhythm in alertness is high at this time (Lavie, 1986; Åkerstedt, 1990). It can also be difficult to sleep at this time of the evening due to social and domestic pressures.

2.3.5.2 Length of work duties

Extended duties are often associated with elevated levels of fatigue due to the combination of the time spent working on a task and the increased duration since the last sleep period (Baker and Ferguson, 2004). Studies which have compared 8- and 12-hour shifts suggest that longer work shifts result in:

- greater fatigue (Macdonald and Bendak, 2000);
- a higher risk of falling asleep during the shift (Sallinen *et al.*, 2003); and
- poorer safety-related performance towards the end of the shift (Baker *et al.*, 1994; Tucker *et al.*, 1998).

2.3.5.3 Number of consecutive work days/nights

The accumulation of fatigue associated with working over successive days or nights can be related directly to sleep loss. As the number of consecutive work days or nights increases, the opportunity for recovery sleep decreases and fatigue increases (Spencer and Robertson, 2000; 2002). Laboratory studies have also demonstrated that restricting sleep to six hours or less over a period of one to two weeks results in performance decrements (Belenky *et al.*, 2003; Van Dongen *et al.*, 2003).

2.3.5.4 Breaks

Taking a break from activity is a short-term countermeasure against mental and physical fatigue (Neri *et al.*, 2002; Tucker, 2003). Studies of aircrew conducted at night in an aircraft simulator have shown that regular short breaks improve subjective ratings of sleepiness (Neri *et al.*, 2002). When an individual can choose the timing of the break, the benefit of short breaks as a fatigue management strategy has also been shown to be higher (Tucker, 2003).

Other factors that have been shown to contribute to fatigue include workload, the predictability of work and the nature of the task (Spencer and Robertson, 2000; 2002).

Where an individual is exposed to a combination of these individual, environmental and work-related factors, a high level of fatigue could be experienced. For example, a shiftworker may find it difficult to obtain sleep during the day when circadian rhythms dictate that the body is in a natural state of high alertness, while daytime environmental conditions (particularly temperature, noise and light) may further reduce the quality and quantity of sleep obtained. In addition, work-related factors such as the length of duty and the amount of time off between duties may reduce the time available for the individual to obtain sufficient sleep. Finally, when not at work the individual may sacrifice sleep in order to meet social and family commitments.

2.4 The effects of fatigue

Having described the range of factors that can contribute to fatigue, this section focuses on the consequences of fatigue. Over the past 50 years considerable research has investigated the effects that fatigue has on performance and, in turn, researchers are increasingly exploring the relationship between fatigue and safety. Fatigue-related safety events have adverse consequences for the individual, but can also impact on co-workers, the organisation for which he or she works, and even the broader community.

2.4.1 Effects of fatigue on individuals

2.4.1.1 Effects on neurobehavioural performance

There is ample scientific evidence to demonstrate a link between sleep loss and declines in cognitive function (Beaumont *et al.*, 2001; Lieberman *et al.*, 2002), impaired performance (Dinges *et al.*, 1997; Harrison and Horne, 2000), and increasing error rates (Neri *et al.*, 1992; Gander *et al.*, 2000). The effect of fatigue on skills such as maintaining vigilance over prolonged periods has been demonstrated consistently: indeed, vigilance is one of the skills most readily affected by fatigue. Given that driving is a task which relies on skills such as attention, prolonged vigilance and reaction time, it is unsurprising that it is a skill which is highly susceptible to fatigue.

To assist us in gauging the extent to which fatigue impairs performance, researchers have compared the effects of fatigue with those of alcohol. One laboratory study found that being awake for around 17 hours causes impairment on a range of cognitive tasks equivalent to that associated with a blood alcohol concentration (BAC) of 0.05%, the legal limit for driving in most of Europe (Dawson and Reid, 1997). Being awake for 24 hours produced cognitive impairment equivalent to that associated with a BAC of 0.1%, greater than the legal limit for driving in the UK.[1]

Our ability to self-assess the impact fatigue is having on our performance and the related increase in risk is not always reliable. While studies suggest that self assessments of fatigue are reasonably accurate (Jones *et al.*, 2006), little research has been conducted on how fatigue influences safety-related decision making. Nonetheless, intuitively it seems evident that we can underrate our own fatigue risk when presented with financial and social incentives and/or the disincentives or inconvenience associated with managing fatigue, for example, pulling over to have a nap.

2.4.1.2 Effects of fatigue on health

The previous section described some of the acute effects of fatigue on performance. Research has also shown that chronic sleep loss can be a risk factor in a range of serious illnesses. Sleep loss has been shown to be a risk factor for obesity and diabetes (Knutson and Van Cauter, 2008), while shiftwork has been shown to increase the risk of gastrointestinal problems (Monk and Folkard, 1992). Recent research has also suggested a possible link between the circadian disruption associated with night shiftwork and an increased risk of cancer (Straif *et al.*, 2007).

1 At the time of writing the UK drink-drive limit is 0.08% BAC or 80 mg alcohol in 100 ml of blood.

2.4.2 Fatigue costs for the organisation

When employees suffer from fatigue, the organisation employing them can be affected by reduced productivity, reduced morale, increased absenteeism and increased accident rates (Dawson *et al.*, 2000). Increased absenteeism could be linked to the adverse health effects that are associated with fatigue. A study of 16,000 European workers showed that shift workers are more likely to be absent than day workers and absences that lasted 20 or more days are higher for shift workers (European Foundation for the Improvement of Living and Working Conditions, 1999). In addition, a recent study suggests that both productivity and safety may be compromised by non-standard working hours (Folkard and Tucker, 2003).

While these effects can impact on the 'health' of an organisation, it is often the case that the true extent of fatigue and its associated costs are hidden because the organisation fails to collect data on fatigue. As a result, it is likely that many organisations persist with practices that contribute to fatigue because these practices are perceived to produce short-term benefits, while the true long-term costs to the organisation go unrecognised.

2.4.3 Fatigue costs for the community

Severe incidents caused by fatigue can have a devastating effect on communities and the environment. An example of such an extreme incident is the oil spill caused by the running aground of the Exxon Valdez in 1989, which has been linked to fatigue as a contributing factor (NTSB, 1990; Folkard and Lombardi, 2006).

It has been argued that organisations that operate with a high fatigue risk reap the short-term benefits of increased productivity, while effectively outsourcing the associated accident and health care costs to the community (Dawson and McCulloch 2005a). For example, the majority of the financial costs of a fatigue-related collision are paid for by society, through taxation, even where the driver who caused the collision was driving for work (ETSC, 2001). When a driver causes an RTC, the community suffers through the costs of providing emergency and medical services as well as through the grief and suffering of affected family members, and 'a decrease in general community participation, increases in counselling and childcare requirements' (Dawson *et al.*, 2000: 5).

Even excluding industrial accidents and transport crashes, the financial costs of fatigue for the community are significant. It has been claimed that fatigue costs the USA an estimated $6,000 million in health costs and $55,000 million a year in lost productivity (Marchant, 1999).

2.5 Driver fatigue

One of the first fatigue-related road collisions to attract national attention in the UK was the M40 minibus crash that occurred just before midnight on 17 November 1993. The minibus was transporting 14 children home from a concert at the Royal Albert Hall in London when it veered off the motorway and collided with the rear of a maintenance truck parked on the hard shoulder. The driver of the minibus and 10 of the children died at the scene of the collision and a further two children died in hospital from injuries sustained. At the inquest, the jury were told that the crash was a 'classic case of falling asleep at the wheel' and that the driver, the children's music teacher, 'almost certainly dozed off just before the accident' (Mackinnon, 1994).

Another example of a particularly injurious fatigue-related collision in the UK is the Selby rail crash (a.k.a. the Great Heck Rail disaster) of 2001, which was described by the judge presiding over the case as 'perhaps the worst driving-related incident in the UK in recent years' (BBC News, 2002). Ten people died and 70 more were injured when a commuter train collided with a car and deflected into the path of a freight train (BBC News, 2002). The driver of the car was found guilty of causing death by dangerous driving and was jailed for five years after it was found that he had fallen asleep behind the wheel (BBC News, 2002).

2.5.1 Effects of fatigue on driving performance

Driving is highly susceptible to fatigue because it involves many of the skills that are impaired by fatigue, such as vigilance. The initial effects that fatigue has on driving performance include (NRTC, 2001):

- decreased attention to safety-related tasks;
- staring vacantly at one specified point;
- delays in changing speed;
- slower reactions;
- impaired visual scanning;
- slowing down; and
- decreased willingness to overtake.

Unless remedial action (i.e. recovery sleep) is taken, the individual's state will decline still further which may lead to more pronounced effects on their driving performance (listed below) (NRTC, 2001):

- a lack of awareness of driving behaviour;
- slower steering responses;
- zigzagging within the lane;

- crossing the centre line;
- running off the side of the road; and
- falling asleep at the wheel.

In Section 2.4.1 it was explained that we are not always able to accurately assess the extent to which our performance is impaired by fatigue. Accordingly, a number of studies have found that drivers fail to appreciate the extent to which their performance is impaired by fatigue (Wylie *et al.*, 1996). Additionally, in a study conducted in North Carolina, USA, even drivers who admitted to having fallen asleep behind the wheel reported that they had not been drowsy before they fell asleep (Stutts *et al.*, 2001).

When drivers are aware of fatigue there is little they can do in the vehicle to reduce fatigue or to protect their performance from fatigue. Research has shown that the things drivers typically do in an attempt to alleviate the symptoms of fatigue (e.g. winding down the window to obtain fresh air, playing loud music) have only a very limited effect (Reyner and Horne, 1998). Drivers may also try to compensate by increasing the task demands (e.g. driving faster so that a 'new' sensation of driving spurs adrenaline and attention levels) or lowering them (e.g. increasing the safety margins by slowing down or using larger following distances). However, the combination of fatigue and increased effort to compensate for fatigue leads to increasingly unstable and variable performance (ERSO, 2006). The only effective way a tired driver can mitigate their fatigue risk is to stop and get some sleep.

2.5.2 Scale of the driver fatigue problem

Although fatigue is a significant safety risk for many different modes of transport (NTSB, 1999), it is on the roads that fatigue causes the most injuries and fatalities worldwide (HRSCCTA, 2000). An analysis of UK road casualty data (Flatley *et al.*, 2004) concluded that 17% of RTCs occurring on major trunk roads which resulted in injury or death were sleep-related.[2] In Australia between 20–30% of fatal road crashes are considered to be caused by fatigue (HRSCCTA, 2000) and in the USA the National Highway Traffic Safety Administration has estimated that fatigue was involved in an average of 56,000 vehicle crashes per year in the mid-1990s (NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness, 1998). The same study concluded that fatigue was responsible for over 1,500 fatalities per annum on the road.

The reported figures on the prevalence of fatigue-related RTCs are of added concern because it is likely that they underestimate the extent of the problem. One of the key difficulties with analysing accident databases for fatigue is that there is poor and

2 The percentage of sleep-related RTCs was found to vary between 3% and 30% depending on the road studied.

limited data present (Gander and James, 1998; Dobbie, 2002). Accident databases are typically fed by police reports and the police do not always consider fatigue as a possible cause of collisions (Dingus *et al.*, 2006; Gander and James, 1998). At the most basic level, in the US, this is because the accident report forms that the police use have check-boxes for noting down the likely cause of the collision, but there is not always a check-box for fatigue (Dingus *et al.*, 2006).

In the UK the form used by the police to record accident data (STATS 19), which is then used by the Department for Transport to generate annual road casualty statistics (*Road Casualties Great Britain* (RCGB)), was recently amended to include fatigue as a contributory factor. While it is likely that there will still be some under-reporting of fatigue (e.g. where the police cannot be conclusive that fatigue was the cause), the Department for Transport can be reasonably certain that the prevalence figures obtained via this method represent at least a minimum value. Since 2006, a number of police forces in the UK have also begun to use a checklist developed specifically to assist investigating teams to identify collisions where tiredness is suspected (Jackson, 2007).

The extent of driver fatigue has also been quantified in driver surveys. A survey of UK drivers (Maycock, 1997) found that 29% of respondents had felt close to falling asleep while driving in the past year.[3] A survey in Norway (Sagberg, 1999) found that 10% of males and 4% of females admitted to falling asleep while driving during the previous 12 months; 4% of these resulted in a crash. A telephone survey of drivers in Ontario, Canada (Vanlaar *et al.*, 2007), found that 14.5% of drivers said they had fallen asleep at the wheel or nodded off while driving at least once in the previous year. In common with analyses of accident databases, driver surveys may also underestimate the extent of the driver fatigue issue and, as the above results show, the phrasing of the question can have a significant impact on respondents' answers.

A final reason that the driver fatigue problem is underestimated is that we have tended to focus on accidents where it is clear that a driver has fallen asleep, whereas a higher proportion of collisions occur when drivers are inattentive or make mistakes due to fatigue (Dinges, 1995). In Australia, for example, unless there is strong evidence that a driver fell asleep at the time of a collision, coroners are unlikely to consider fatigue to have been a contributory factor (Dobbie, 2002). Furthermore, often collisions are attributed to driver inattention, although the cause of driver inattention is not recorded or investigated and that cause could be fatigue (Stutts *et al.*, 1999).

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3 Maycock (1995) also highlighted the importance of road type in relation to driver fatigue: on motorways it was estimated that fatigue accounted for 20% of all accidents, as opposed to 7% of crashes on roads within urban areas and 14% for roads outside urban areas.

2.5.3 *Costs of driver fatigue*

The high risk of fatigue-related injury or death on the road (Department for Transport, 2001) added to the high costs that the injuries and fatalities suffered in RTCs have for the community (Clarke et al., 2005), mean that the costs arising from fatigue-related RTCs are considerable. In Australia, fatigue-related road crashes are estimated to cost A$3,000 million and fatigue-related heavy vehicle collisions are estimated to cost A$300 million (HRSCCTA, 2000). In the USA, fatigue-related collisions involving truck drivers are estimated to cost $5,000 million annually (Marchant, 1999). Although no official figures have been calculated for the UK, using Department for Transport estimates of the number of serious and fatal road collisions involving fatigue and the estimated costs of serious and fatal collisions,[4] the financial costs of fatigue-related collisions amount to *c*. £1,600 million per year.

2.6 Work-related driver fatigue

Several studies have estimated the prevalence of fatigue-related collisions involving lorries, and these demonstrate that driver fatigue appears to be a particular problem for LGV drivers:

- In the US the National Transportation Safety Board (NTSB) judged 58% of 107 single LGV crashes to be due to fatigue and in 18% of those crashes the driver fell asleep at the wheel (NTSB, 1995). In Australia, it has been estimated that up to 50% of fatal single-vehicle semi-trailer collisions are caused by fatigue and up to 60% of LGV collisions have fatigue as a contributory factor (Feyer and Williamson, 2001).
- A report by the European Transport Safety Council (ETSC, 2001) claims that the evidence for fatigue-related crashes involving commercial drivers in Europe is less comprehensive than evidence in the US and that European studies are likely to underestimate the role of fatigue. However, the report does cite a study in Germany in 1994, with results that are more in line with the results of US studies than other European studies. This study found that fatigue was the cause of 26% of crashes involving LGVs over 7.5 tonnes and 36% of crashes involving commercial vehicles of less than 7.5 tonnes.

Driver survey and interview studies similarly show that fatigue-related incidents are prevalent and widespread among LGV drivers. In a study conducted in France in 1999, 62% of long-haul lorry drivers (n = 345) agreed that they had 'blanked out' or 'dropped off for a moment' behind the wheel during their career (ETSC, 2001). In a study conducted in the US, two-thirds of 593 LGV drivers that were interviewed reported driving while drowsy within the previous month, 47% had fallen asleep at

4 This estimation was calculated using two Department for Transport statistics: the cost of preventing road traffic collisions resulting in serious injury or death (Department for Transport, 2007a); and research (Flatley *et al.*, 2004), which estimated that 17% of road traffic crashes resulting in injury or death were fatigue-related.

the wheel at some point in their driving career, and 25% reported falling asleep at the wheel at least once during the previous year (McCartt *et al.*, 2000). In a survey of 1,007 LGV drivers in Australia (Williamson *et al.*, 2001), 21.1% reported at least one fatigue-related incident on their last trip. The most common of these were: crossing lane lines (11.3% of drivers); nodding off (5.3%); having a near miss (5%); and over- or under-steering (5%).

These surveys indicate that fatigue-related incidents are prevalent and widespread among LGV drivers. Additionally, of commercial drivers, it is not only lorry drivers who suffer from fatigue on the road. In the UK the RAC reports that company car drivers are more likely to have accidents resulting from falling asleep at the wheel than other drivers (Clarke *et al.*, 2005) and research suggests that between 25% and 33% of all fatal and serious crashes on UK roads involve a driver who was at work at the time (Work-related Road Safety Task Group, 2001).

2.6.1 The causes of commercial driver fatigue

The inadequate sleep obtained by commercial drivers is widely considered to be a key determinant of fatigue in transport (Fatigue and Transport Working Party, undated). The important role that sleep plays in determining fatigue-related RTCs is evident in a study by the US National Transportation Safety Board (NTSB, 1995) which found that drivers of goods vehicles involved in fatigue-related crashes had an average of 5.5 hours in the 24 hours before the crash compared with an average of 8.8 hours of sleep for drivers involved in other types of crashes. Similarly, Arnold and Hartley (1998) found that truck drivers who had obtained less than six hours of sleep reported:

- three times more hazardous incidents than those with more sleep;
- nodding off at the wheel 2.5 times more often than those with more sleep; and
- using stimulant drugs to stay awake twice as often as drivers who had obtained more than six hours' sleep.

The sleep loss that professional drivers encounter is largely a product of the way that their work is organised and the nature of the road haulage industry (NRTC, 2001). The time-sensitive nature of the road haulage industry, and consumer and customer demands, can contribute to fatigue by creating fatigue-inducing delivery schedules (Beilock, 1995; NRTC, 2001). Drivers are often expected to work long hours and to deliver goods within a tight time framework to meet customer and consumer demands any time of the day or night.

The demands of the road haulage industry contribute to a long hours culture. In the UK, Europe, the US and Australia, it is possible for drivers to work at least 10–12 hours in a 24-hour period and studies have shown that they often do work these hours (Buxton and Hartley, 2001), or even that they violate driving limitations and drive for longer than the law allows (TranSafety, 1998). For example, in a US survey of 593 truck drivers, almost 20% reported that they ‘always or often’ exceeded the 10-hour driving limit of the Federal Highway Administration Hours-of-Service regulations (TranSafety, 1998). A US survey of 498 long-distance drivers, for example, suggested that difficult or unreasonable delivery schedules are a major cause of fatigue (Beilock, 1995). In this study more than a quarter of drivers had delivery schedules which violated regulated working time limitations.

Many professional drivers also work shiftwork and thus incur the fatigue associated with extended hours of wakefulness and the conflict between the timing of sleep/wakefulness, the body clock and the activities of others (Horne and Reyner, 1995; Wylie, 1998). Other aspects of the road haulage industry which promote fatigue include the following:

- Payment systems (NRTC, 2001) – payment which is connected to results (e.g. pay per kilometre driven, pay per load delivered) can provide an incentive for drivers to work long hours, thus inadvertently contributing to driver fatigue.
- A lack of safe and comfortable rest areas (Koklanaris, 2000) – drivers need to be able to stop to take a break or have a nap when necessary; however, their ability to do so is dependent on the availability of safe and comfortable facilities.
- Loading or delivery queues – drivers have reported being kept waiting in long queues before being able to offload their goods. In a survey of long-distance LGV drivers in Australia (Williamson *et al.*, 2001), loading queues were reported to be the most common cause of loading and unloading delays.
- Obstructive sleep apnoea – research indicates that sleep-disordered breathing, obstructive sleep apnoea (OSA) and excessive daytime sleepiness are widespread among commercial vehicle drivers (Howard *et al.*, 2004) and these sleep disorders intensify the risk of an RTC (Stoohs *et al.*, 1994; Howard *et al.*, 2004; Fidan *et al.*, 2007). A study from the USA reports that over 800,000 drivers were involved in RTCs caused by OSA in 2000 (Sassani *et al.*, 2004).

Other factors that also have an influence on fatigue in the road transport industry include: heightened competition; increasing financial and lifestyle expectations of employees; management pressure to decrease employee numbers (Dawson *et al.*, 2000); and the informal truck driver ‘pooling’ system in the UK, whereby drivers are called upon by large operators when required (RoSPA, 2001).

2.7 Summary – the problem of fatigue, causes, effects and the road transport industry

- Fatigue is defined as a combination of symptoms, including impaired performance, slower reaction times and subjective feelings of tiredness.

- Fatigue is caused by a multitude of factors that can be divided into three main categories: (1) the individual, (2) environmental and (3) work-related. Most of these factors cause fatigue by reducing sleep duration, extending hours of wakefulness or disrupting the timing of sleep and wakefulness.
- Fatigue has adverse consequences for (1) individual health, safety and well-being, (2) organisational safety and productivity and (3) the community often picks up the costs in terms of the lost time, emergency services and medical care required after a fatigue-related accident.
- In the UK approximately 20% of collisions on motorways are caused by fatigue and fatigue-related crashes resulting in injury or fatality cost an estimated £1,600 million per year.
- The road transport industry is associated with a culture of long work hours and shiftwork. Consequently, the incidence of fatigue-related RTCs is magnified among commercial drivers.

From what has been discussed so far, it is clear that commercial driver fatigue is prevalent and costly. Although the adverse consequences that fatigue has for health, safety and productivity cannot be eliminated completely, effective management strategies can minimise the risk it poses. The next section considers strategies that are commonly used to address the fatigue risk of commercial drivers and other safety critical workers.

3 THE PRESCRIPTIVE APPROACH TO FATIGUE MANAGEMENT

3.1 Introduction

As Section 2 showed, fatigue has a variety of causes: individual, environmental and work-related. For fatigue risk to be managed effectively, all of these causes need to be considered, which requires that both individuals and the companies for which they work need to be engaged in and responsible for managing fatigue. However, to date regulators and operators have largely used compliance with prescriptive hours of work (HoW) limitations, such as driving hours, to provide protection against fatigue (Dawson and McCulloch, 2005b; Cabon *et al.*, 2008). Section 3 explores the effectiveness of the prescriptive approach to fatigue management:

- Section 3.2 consists of an explanation and examples of HoW limitation schemes;
- Section 3.3 explains why, when used in isolation, HoW limitations provide inadequate protection;
- Section 3.4 discusses fatigue management strategies other than HoW limitations which are used by some organisations in the transport industries;
- Section 3.5 explains why using these fatigue management strategies in isolation is problematic; and
- Section 3.6 summarises the main points of Section 3.

3.2 Prescriptive limitations on work hours

The Hours of Service Act of 1907, which limited the duty time of railway engineers in the USA, was the first regulation to prescribe limits on hours of work (HoW) for safety reasons (Jones *et al.*, 2005). Since then, governments around the world have imposed a range of legal HoW limits for controlling the fatigue, health and well-being of workers. HoW limitations tend to be relatively simple and typically consider the maximum number of hours that can be worked per day and the minimum duration of rest periods.

The transport industry is particularly highly regulated when it comes to work hours and is usually controlled using specific rule-sets. In the EU, commercial aircrew (pilots and cabin crew) must work within Subpart Q (EU-OPS Regulation 1899/2006), while seafarers are covered by the Seafarers' Directive (1999/63/EC). For commercial drivers, a range of regulations may apply (described in the next section), depending upon the size and type of vehicle (e.g. large goods vehicle (LGV) or passenger carrying vehicle (PCV)).

The most restrictive HoW limitations schemes are found in the aviation industry, likely because of the devastating loss of life that can occur in an aviation accident . The nature of the aviation industry also means that HoW limitations can be relatively complex. For example, some aviation limits consider factors such as the number of separate flights operated per duty, the duration of individual flights and the number of time zones crossed (Cabon *et al.*, 2002).

However, when we consider the differences in HoW limitations between transport sectors, the differences do not always seem logical or justifiable. For example, according to current EU regulations, a pilot can fly a maximum of 100 hours per 28-day period, while a seafarer could work up to 288 hours. Similarly, according to US regulations applicable in 2005, a pilot could fly a maximum of 100 hours a month, while a train engineer could work up to 432 hours (Jones *et al.*, 2005). It seems difficult to understand how such large differences in maximum working hours between pilots and train engineers could be justifiable, particularly 'as a major incident in either modality can cause significant injury to individuals' (Jones *et al.*, 2005: 246).

To complement HoW limitations there is typically a regulatory requirement for employees to be fit for work. For example, the EU regulations for pilots state:

> 'A crew member shall not operate an aeroplane if he/she knows or suspects that he/she is suffering from or is likely to suffer from fatigue or feels unfit, to the extent that the flight may be endangered.'
> ('Subpart Q' of EU-OPS Regulation 1899/2006, L377/162)

3.2.1 The prescriptive limitations that apply to commercial drivers in the EU

In the UK, the work and driving hours of goods and passenger vehicle drivers are regulated using a number of complementary sets of HoW limitations. European Union Drivers' Hours Rules and Regulations (Regulation [EC] 561/2006; the EU Drivers' Hours Rules) apply to LGV drivers (for goods vehicles that exceed 3.5 tonnes) based in the UK, while they are driving both in the UK and in the European Union (VOSA, 2007a). Passenger vehicles carrying more than 9 people are also subject to the EU Drivers' Hours Rules, while 'domestic rules' apply to drivers of most other goods and passenger vehicles when they are in the UK (VOSA, 2007a; 2007b).

The EU Drivers' Hours Rules are standardised for countries that belong to the European Union, as well as Switzerland and countries that are part of the European Economic Area (EEA) (VOSA, 2007a). Vehicles operating in countries which belong to the AETR (European Agreement concerning the Work of Crews of Vehicles engaged in International Road Transport), for example Russia, need to conform to the AETR rules (VOSA, 2007a). There are no substantial differences between break times, rest times and driving time limits between the EU and the AETR rules (VOSA, 2007a).

HoW limitations usually specify more than driving/work limits and minimum rest periods. For example, for LGV drivers they may also determine how long a driver may drive before a break needs to be taken and the duration of the break (VOSA, 2007). HoW limitations may also limit night work or early morning shifts, and the type and number of transitions from day to night shifts. In the UK, LGV drivers are also subject to the Road Transport (Working Time) Regulations (2005) which further limit their hours and specify breaks (Department for Transport, 2007b). For example, under these regulations, a driver cannot work for more than 10 hours at night in a 24-hour period (Department for Transport, 2007b).

3.3 Advantages and criticisms of prescriptive HoW limitations

The prescriptive approach to fatigue management has a number of strengths. HoW limitations are usually simple rules with which to comply (Jones *et al.*, 2005), they provide consistent, unambiguous guidelines to scheduling personnel (Holmes *et al.*, 2006a), and offer protection for employees by stating what is and is not allowed in terms of work hours (Holmes *et al.*, 2006a). However, it is clear from the high incidence of fatigue-related crashes among professional drivers that our approach in this industry needs improvement or revision.

One criticism of HoW limitations for drivers is that they depend on the compliance of the drivers and the companies for which they work. In surveys of Australian (Arnold and Hartley, 1998) and American (TranSafety, 1998) truck drivers, 38% and 20% drivers admitted to exceeding their legal work time limitations, respectively.

More recently, however, deeper criticisms have been levelled at the use of HoW regulations as a strategy for preventing fatigue-related accidents, and a number of regulators have begun to recognise that HoW limitations alone cannot provide adequate protection from fatigue risk. Transport Canada, for example, has expressed concerns over prescriptive approaches to fatigue management:

> ‘Traditional approaches to fatigue based on prescriptive limits to duty times were unlikely to be effective in improving safety, could be unwieldy, and unnecessarily expensive with respect to compliance and enforcement.’
>
> (Booth-Bourdeau *et al.*, 2005 : 3)

Meanwhile, in the UK the Civil Aviation Authority (CAA) has criticised the static and limited nature of prescriptive approaches:

> 'We find that the prescriptive approach to dealing with fatigue risk results in a static form of safety management, which only provides a single level of control and is unresponsive to the modern high workload environment.'
>
> (Brown, 2006: 4)

In Australia, the Civil Aviation Safety Authority (CASA) has expressed similar concerns:

> 'The current system for managing fatigued aircrew in Australia is Civil Aviation Order 48. It is prescriptive, relatively inflexible and is not based on scientific principles; rather it is largely based on industrial practices in existence at the time of its development.'
>
> (Fletcher, 2007: 2)

One of the key criticisms made by researchers is that HoW limitations are simplistic and do not give due consideration to the range of factors relating to work hours that contribute to fatigue (Dawson and McCulloch, 2005a). Recent research (Jones *et al.*, 2005) has assessed the extent to which the regulations that apply to the road, rail, aviation and marine sectors in the UK, Canada, the US and Australia take account of the following known contributors to fatigue:

1. Time of day – is night work taken into account?
2. Circadian adaptation – are circadian rhythms taken into account?
3. Duration of sleep opportunity – is a period of greater than eight hours off provided as a minimum of time off after a duty?
4. Sleep quality – do regulations consider whether sleep will occur outside of the worker's (work) hours?
5. Predictability – is there a requirement for sufficient warning to be given for changes to the start time of a duty?
6. Sleep debt – do the regulations provide for an extended sleep period of greater than 34 hours?
7. Time on task – is the primary task limited to a maximum of 12 hours?
8. Short breaks – do the regulations provide for short breaks?

The fatigue contributor that the prescriptive rules were most likely to address was 'sleep duration', with 10 of the 17 regulations providing greater than eight hours off as a minimum after duties. The fatigue contributor that the prescriptive rules were least likely to address was 'circadian adaptation', with only the UK aviation's CAP 371 taking circadian rhythms into account. If HoW limitations, as the analysis found, do not address the most important factors that have an impact on fatigue, then they are unlikely to be effective in mitigating the risk of fatigue. Furthermore, the study also found that where the regulations considered a greater number of fatigue-related factors, the benefits of HoW limitations became lost because the regulations became very complex:

> 'For example, the driving regulations in the UK are simple to comply with, but they only address three factors. Conversely, the UK aviation regulations address six factors, but are very complicated in terms of comprehension and compliance.'
>
> (Jones *et al.*, 2005: 246)

Only one of the 17 HoW regulations considered by Jones *et al.* (2005) took account of the circadian rhythm in alertness. This finding is of particular note because, as described in Section 2.3.2, the circadian rhythm in alertness has a potent influence on how alert we feel across the 24-hour period, the ease with which we fall asleep, and the amount of sleep we can obtain at different times of day. HoW limitations have been criticised because they conceive of fatigue, incorrectly, as a function purely of the amount of time awake and the amount of time asleep, and fail to take account of circadian rhythms (Dawson *et al.*, 2000; RoSPA, 2001; Jones *et al.*, 2005). For example:

> '. . . because of the circadian rhythms a break will not have the same recovery value depending on the time of the day, the timing of the break being more important than the duration of the break itself. Therefore a prescriptive approach [such as HoW limitations] cannot take into account all the complexity and interactions of factors that are linked to the hours of work.'
>
> (Cabon *et al.*, 2008)

Further criticism of prescriptive HoW limitations stems from the fact that the same limits are placed on all operators; an approach which is colloquially known as 'one size fits all'. HoW limitations fail to take account of a variety of individual determinants of fatigue, for example, inter-individual differences such as age, experience and chronotype (see, for example, Van Dongen and Dinges, 2005; Van Dongen *et al.*, 2005). The limits do not address the different levels of fatigue encountered by different individuals when performing different tasks, nor do they take account of the variation in the level of risk associated with different tasks (Holmes *et al.*, 2006a) and how this may vary over time. For example, the EU Driver's Hours Rules are equally applicable in summer and winter, but the additional workload associated with driving in hazardous icy conditions could make winter driving more fatiguing than summer driving.

The simple and static nature of HoW limits has two potential disadvantages for safety. First, by ignoring the influence of multiple determinants of fatigue, there is a disconnection between what is allowed/not allowed and what is safe/unsafe (Dawson *et al.*, 2000). In some situations operators are allowed to work when fatigue risk is high and in others they are not allowed to work when fatigue is low. For example, a study conducted by easyJet Airlines Ltd (easyJet) compared fatigue risk on a roster that fell within the existing flight time limitations (6/3 roster consisting of three early duties, three lates and three days off) with that associated with a trial roster that fell outside of the regulations (5/2/5/4 roster consisting of five early duties, two days off, five late duties, four days off). The 5/2/5/4 roster was reportedly associated with 'a significant reduction in fatigue risk and flight deck error' (Stewart *et al.*, 2006).

Second, as rule sets apply equally to all operators, regardless of their safety culture or the quality of the safety systems they put in place, there is limited motivation to innovate or implement additional controls. There is also limited encouragement for other parties in the supply chain to manage fatigue risk. As discussed in Section 2.5.4, customer demands and delivery queues, over which neither a driver nor his/her employer may have control, are major contributors to commercial driver fatigue. HoW limitations do not consider the role of other parties in the supply chain for managing fatigue risk.

Some of the criticisms of HoW limitations could be addressed simply by improving the existing HoW. For example, HoW limitations could be adapted to give better consideration to time of day. However, in isolation, improving the rules would not address the key criticisms that work hours are only one source of fatigue and that HoW limitations do not take account of differences between operations, working conditions, and risk exposure. The next section looks at the additional controls that organisations have put in place in an attempt to manage fatigue risk more effectively.

3.4 Additional methods for managing fatigue

Although HoW limitations are often the only mandatory requirements for managing fatigue, some proactive organisations have realised that relying on HoW limitations alone is not an effective way of protecting against fatigue risk (Holmes and Stewart, 2008). Additional strategies for managing fatigue risk that are being applied include the following:

- **Research on fatigue** – regulators across Europe and North America, and various safety bodies, for example the Australian Transport Safety Bureau, have commissioned research on the impact of fatigue on transport (Horberry *et al.*, 2008; Wylie *et al.*, 1996; Dobbie, 2002). Such research often aims to determine the levels of fatigue within certain groups in the population, for example, motorcycle riders (Horberry *et al.*, 2008), or the prevalence of fatigue-related incidents (NTSB, 1999). By developing a better understanding of fatigue, research can help to determine where best to direct resources for addressing fatigue risk.

- **Awareness campaigns** – regulators and road safety bodies also commonly work to raise the public's awareness of the dangers of driver fatigue through road safety campaigns (Jettinghoff *et al.*, 2005). For example, in the UK the Department for Transport's road safety publicity campaign, 'Think!' (Department for Transport, 2008), includes television and radio advertisements, as well as posters and leaflets, which aim to increase awareness of the risks of tired driving. Raising drivers' awareness of the early warning signs of fatigue, for example, may help them to recognise when they are too tired to drive and what effective countermeasures they could implement to counteract the problem. However, research has shown that, on their own, awareness campaigns are not effective in preventing crashes or in encouraging drivers to stop driving when they are suffering from fatigue (ERSO, 2006).
- **Measuring fatigue** – some proactive organisations have developed ways of measuring fatigue. Perhaps the most common method is the use of computer-based fatigue models that estimate the level of fatigue associated with a work schedule. Fatigue models use 'science-based' algorithms to predict the fatigue associated with work hours, based on variables such as the duration and timing of shifts and breaks. Examples include FAID (Fletcher and Dawson, 1998) SAFE (CAA, 2007) and the Health and Safety Executive (HSE) Fatigue/Risk Index (Spencer *et al.*, 2006).

  In addition, independent reporting systems have been set up (e.g. CHIRP – Confidential Human Factors Incident Reporting Programme) which enable employees to file confidential reports relating to human factors issues, such as fatigue. Recently, a number of proactive organisations have also introduced an in-house confidential fatigue reporting system that enables employees to report instances or concerns relating specifically to fatigue (Holmes *et al.*, 2006b).
- **The training and education of employees** – some operators have developed training programmes for employees to raise awareness of fatigue, and to learn how to tackle the causes of fatigue and which countermeasures they can use to limit the effects of fatigue (Holmes and Stewart, 2008).
- **In-vehicle fatigue detection and warning systems** – over the past 30 years a wide range of in-vehicle systems have been developed to monitor driver or vehicle behaviour for signs of performance impairment which may be due to fatigue. While the technology employed in these devices is improving, a review of in-vehicle sleepiness detection devices commissioned by the Department for Transport warns against relying on these devices, emphasising that they should be used only as a 'fall-back safety aid' and that they cannot provide a substitute to ensuring that drivers have an adequate opportunity for rest (Wright *et al.*, 2007: 1). Many of the devices have been criticised for detecting the signs of fatigue too late in the process (by the time a driver is exhibiting physical signs of

fatigue capable of being detected, the driver's performance may already have deteriorated to unsafe levels), or for being too intrusive (see Wright *et al.* (2007)).

3.5 Fatigue management: why a system-based approach is best

While the adoption of fatigue management strategies in addition to HoW is commendable, there is limited evidence that, in isolation, these strategies enhance the extent to which employees, the organisation and the community are protected from fatigue risk. The reasons why simply applying more controls for fatigue is unlikely to be the most effective approach to managing fatigue are listed below:

- Fatigue is not measured using an organised, systematic approach – when companies adopt fatigue measurement techniques, such as fatigue modelling, they are often used sporadically and the output is not linked to the output of other data collection systems. Information on fatigue is provided in 'snap-shots' and a systematic approach to fatigue measurement is required to provide comprehensive understanding of the risks to which an organisation is exposed:

  > 'combined information from different elements – such as hours of work assessments in conjunction with assessments of work environments – would provide a much more comprehensive view of expected fatigue within an operation as compared to either element on its own.'
  >
  > (Fletcher, 2007: 5)

- Fatigue management is not part of the day-to-day business of the company – fatigue management, and the management of other safety risks, is considered to be most effective if it is conducted as part of the everyday business of a company (ALPA, 2006; ICAO, 2008). Thus, instead of relying on isolated and sporadic controls, fatigue management should be considered regularly at all the relevant levels of the organisation, including in the boardroom.
- Fatigue training and awareness campaigns for employees can assume that fatigue management is essentially the responsibility of employees. However, effective fatigue management is the shared responsibility of both employees and employers as the cause of fatigue may stem from individual factors, for example health and the home environment, and work-related factors, such as the roster or work environment. Moreover, as described in Section 2.4, the consequences of fatigue impact on both the individual and their employer.
- There is no clear accountability for fatigue – when isolated fatigue control measures are used, who is accountable for managing fatigue risk in the organisation is seldom considered and identified. A lack of clear accountability

makes it less likely that one individual will take ‘ownership’ of a risk and manage that risk effectively.

- Fatigue management strategies tend to be reactive – isolated fatigue management strategies are likely to be implemented reactively in response to a safety incident. However, effective fatigue risk management also requires a proactive approach so that a company is aware of the particular risks they face and have strategies in place to minimise these risks, before an incident occurs. The importance of using both reactive and proactive approaches to risk management was emphasised by an enquiry into the Waterfall Rail accident that occurred in New South Wales, Australia, in 2003:

  > ‘A reactive approach to incidents or accidents is obviously necessary in any risk management system, but it must not be the only approach. Such an approach will not capture low probability high consequence events of the kind that materialised at Waterfall. That is why a rigorous process of overall risk assessment must be carried out.’
  >
  > (McInerney, 2005: 118)

- Multiple layers of defence are not provided – Dawson and McCulloch (2005a) suggest that an individual fatigue management strategy, or a random selection of strategies, cannot provide the necessary depth of protection. The researchers suggest that effective fatigue management involves the structured implementation of multiple, overlapping controls and that this cannot be provided by sporadic and isolated strategies.

  Based on Reason’s model of accident causation (Reason, 1997), commonly referred to as the ‘Swiss Cheese’ model, Dawson and McCulloch (2005a) have developed a ‘Defences in Depth’ approach to fatigue management. The model identifies five distinct layers of defences which need to be put in place to guard against a fatigue-related incident.

  The five layers of defence are:
  1. Take steps to ensure that employees are provided with the opportunity to obtain adequate sleep, for example by analysing rosters using fatigue modelling software.
  2. Take steps to ensure that employees use their rest opportunities to obtain adequate sleep, for example by providing company rest facilities where required.
  3. Put in place systems to detect and manage fatigue-related behaviours, for example educate employees on how to detect fatigue and provide them with strategies that can be used to tackle fatigue.
  4. Put in place systems to monitor the occurrence of fatigue-related errors, for example an employee fatigue reporting system.
  5. Investigate the contributory roles that fatigue may have played in incidents.

Dawson and McCulloch's model proposes that the effective management of fatigue requires multiple layers of defences rather than isolated or sporadic strategies. In recent years an approach has been developed which addresses the limitations identified in this section, an approach which integrates multiple fatigue controls into a scientifically-based system for managing fatigue. This approach is termed a 'Fatigue Risk Management System,' which is the subject of Section 4.

3.6 Summary – the prescriptive approach to fatigue management

- HoW limitations are the primary means by which fatigue is managed and some proactive regulators and operators have implemented additional strategies, for example fatigue management training for employees.
- Research has shown that HoW limitations, at least in isolation, are not always effective for managing fatigue risk. The limits are not based on scientific research, do not take account of risk, the nature of an operation, and only tackle one cause of fatigue.
- While there may be benefits to using additional strategies for managing fatigue, in practice these strategies are not applied in a systematic manner. Fatigue is not comprehensively measured, there is limited recognition of the dual responsibility fatigue management has for employees and the employer, no clear lines of accountability for fatigue risk and the necessary multiple layers of defence are not applied.
- A systematic approach to managing fatigue that improves on HoW limitations and isolated measures for managing fatigue is required and to this end, Fatigue Risk Management Systems (FRMS) have evolved.

4 WHAT IS A FATIGUE RISK MANAGEMENT SYSTEM?

4.1 Introduction

To understand how Fatigue Risk Management Systems (FRMS) have come about, it is important to consider them in the context of broader developments in regulatory strategy and safety management. This section provides background information on outcome-based regulations and Safety Management Systems (SMS) necessary to place FRMS in context, before describing the key components of an FRMS and its benefits for effective fatigue management.

Section 4 is structured as follows:

- Section 4.2 describes the shift in regulatory strategy towards an outcome-based approach.
- Section 4.3 describes the structure of an SMS, which underpins the design of FRMS.
- Section 4.4 introduces FRMS and describes the key components that research and industry guidance suggest should be included in an FRMS.
- Section 4.5 describes how FRMS addresses the limitations associated with hours of work (HoW) limitations and additional isolated controls for managing fatigue.
- Section 4.6 summarises the main points highlighted in Section 4.

4.2 The move towards outcome-based regulations

> 'In simple terms, [an outcome-based] standard may be something like: "People shall be prevented from falling over the cliff". By contrast, in prescriptive regulation the specific means of achieving compliance is mandated, for example: "A one-metre high rail shall be installed at the edge of the cliff."'
>
> (Efthimios Mitropoulos, Secretary-General of the International Maritime Organisation (IMO), cited in Smith *et al.*, 2006: 70)

Regulatory authorities working in a wide variety of industries are increasingly moving away from prescriptive-based regulation, such as HoW limitations, towards outcome-based regulation.[5] Outcome-based regulation involves specifying required

5 For example, in the UK an outcome-based approach is employed by the Health and Safety Executive (HSE) and the Office of Rail Regulation (ORR). Outcome-based regulation is also known as performance-based regulation and principle-based regulation (Coglianese and Lazer, 2003; FSA, 2007).

outcomes, but leaves the means of achieving that outcome to the discretion of the regulated entity (Coglianese, 2003). In terms of fatigue, organisations would be expected to achieve the outcome 'managing fatigue', but this could be achieved in many different ways by different companies. Such an approach encourages companies to measure the fatigue risk unique to their organisation and to develop tailored controls, instead of relying on an isolated 'one-size-fits-all' rule:

> 'From an outcomes perspective . . . using any one specific measure to control fatigue will always result in an [approximate] system which fails to account for the complexity of the work situation.'
>
> (Smith *et al.*, 2006: 70)

To provide more specific guidance on how an outcome needs to be achieved, outcome-based regulations are often broken down into 'standards' against which a company can be audited.[6] For example, a regulator in the road transport industry could specify that, in order for an organisation to achieve the broader outcome 'managing fatigue', it must comply with the following outcome-based standard, among others: the risk of fatigue should be considered when driver rosters and trip schedules are developed. When audited, the organisation would then have to demonstrate how it is fulfilling this standard. Although it may be compulsory for an organisation to comply with the standard, it is outcome-based and not prescriptive, as the regulator does not specify precisely how many hours a driver can work or how rostering and scheduling should take account of fatigue, nor what the benchmark should be for minimising roster-related fatigue.

From a theoretical perspective, the key advantage of outcome-based regulation is that organisations are required to implement the controls that are specifically appropriate to their operating environment and risk exposure. In relation to the management of fatigue risk, this implies that operators implement a set of tailored controls that are more effective than HoW limitations, or equally effective but less costly. This approach can also provide operators with operational flexibility, as it can free them from the burden of unnecessary regulation.

For the regulator, this approach has the benefit of being a better use of its resources. For example, rather than using resources to supervise the compliance of all operators, resources can be directed at investigations of high-risk organisations and at developing support and guidance for operators (Hampton, 2005).

4.3 Safety Management Systems

Outcome-based regulation can only be effective if organisations have effective systems for managing safety in place; thus the increasingly sophisticated approach

6 The trials of FRMS in the road transport industry in Australia and New Zealand, discussed in detail in Section 5, provide actual examples of these kinds of standards.

taken by regulators has coincided with advances in operational safety management and the evolution of Safety Management Systems (SMS). This section provides a brief overview of SMS in order to provide background information necessary to understand the development of Fatigue Risk Management Systems (FRMS).

4.3.1 SMS is a business-like approach to safety

Until relatively recently, safety management was largely a reactive and isolated process. Safety departments investigated events after they occurred and applied the controls deemed necessary to prevent the same event occurring again. As safety was not considered an integral part of the business, safety managers were often not expected or supported to be more proactive. However, effective safety management is now increasingly being viewed as a key business function that enables operators to balance safety, productivity and costs in an informed manner.

An SMS recognises that decisions that affect safety are made throughout the company, including in the boardroom, and not merely by the safety team or by safety critical workers (ALPA*,* 2006; ICAO, 2008). By integrating safety into the everyday business of the company, the commitment of the entire organisation, not merely the safety team, is required. Safety is treated as a core business function akin to financial management or other forms of management (ICAO, 2008).

SMS recognises that an acceptable level of safety is the result of successful management techniques. As with any business plan, an SMS is an organised approach with set goals, levels of authority, policies and procedures, and clear accountabilities for operational safety (ICAO, 2008). It is intended to be a transparent, documented, step-by-step and repeatable process for achieving safety which ultimately becomes an integral part of an organisation's culture, or, in other words, 'the way things are done around here'.

For an SMS to be effective, it is essential that there is open and honest reporting of safety issues within the organisation. Safety reports are a critical source of information and without this information the SMS essentially 'has its eyes closed'. To facilitate open reporting an organisation needs to foster a just culture which recognises that honest human errors are accepted as part of human nature and, with the exception of deliberate violations of rules and established procedures, punitive measures are not usually necessary. People are encouraged, and even rewarded, for providing essential safety-related information, rather than being discouraged from reporting by the threat of possible punitive measures being taken (GAIN, 2004).

4.3.2 Components of an SMS

Table 4.1 lists the typical components of an SMS (CASA, 2002; ROGS, 2006; FAA, 2006).

Table 4.1: Components of an SMS

Component	Description
Safety management policy	A clear statement from the Chief Executive Officer (CEO) of the company's commitment to safety and the SMS, and the accountability and responsibilities of individual employees and groups for the SMS
Risk management	A process for identifying hazards to safety and for evaluating and managing the associated risks
Reporting	A formal, documented process for the internal reporting of hazards and incidents, and for taking corrective actions to prevent their recurrence
Incident investigation	A formal, documented process for investigating safety incidents or accidents and for taking corrective actions to prevent their recurrence
Training and education	A process for ensuring that personnel are trained and competent to perform their duties, including meeting their responsibilities within the SMS
Internal and external auditing	A process for conducting periodic reviews or audits of the SMS

One of the key components is safety risk management: processes for identifying the hazards to which an organisation is exposed, assessing the risks (the probability of the hazard causing adverse events and the severity of those events), and adopting controls to mitigate or eliminate the risks (CAA, 2008). Rather than simply applying controls, for example prescribed limits on HoW, organisations using risk management assess their risk and determine what controls are actually appropriate.

The remaining components of an SMS include policy, reporting, investigation, training and auditing, and are familiar to traditional safety management. However, when incorporated into an SMS, each of these elements are linked into a formal structure and an integrated network of people and other resources aimed at achieving safety (FAA, 2006). For example, the safety policy not only states an organisation's commitment to safety, but also its intent to manage risk as an integral part of its overall business.

Although there are some standard components of an effective SMS, there is no 'one size fits all'. The size and complexity of SMS necessarily varies greatly between organisations depending on a range of factors, including the type and scale of the risks to which an organisation is exposed and the size and the nature of the operation (Stolzer *et al.*, 2008). Where risk is low and static, for example an office environment, minimal controls are required and SMS may not consist of much more than policy, training and an incident reporting system. In contrast, in the transport industry and other safety-critical industries, when risk exposure is dynamic and the consequences of an incident can be catastrophic, a more involved SMS is required.

4.4 Fatigue Risk Management Systems

In the context of the evolution of outcome-based regulation and SMS, it is easy to see how Fatigue Risk Management Systems (FRMS) came about. In the 1990s, government, regulators and operators, concerned about the human and financial costs associated with fatigue, began to recognise that fatigue is 'just another risk' that could be managed using a risk-based and systematic approach. Fatigue risk management gradually gained ground and today can be defined as 'explicit and comprehensive processes for measuring, mitigating and managing' the actual fatigue risk to which a company is exposed (Holmes and Stewart, 2008: 2). It is considered to be most effective when it is integrated into, or supported by, an SMS, thereby forming an FRMS (Dawson and McCulloch, 2005b).

An FRMS can be defined as:

> A scientifically-based, data-driven addition or alternative to prescriptive hours of work limitations which manages employee fatigue in a flexible manner appropriate to the level of risk exposure and the nature of the operation.
>
> (Brown, 2006; ALPA, 2008)

In an FRMS, fatigue risk is managed according to a repeatable, step-by-step process which is planned, transparent and documented. Although there is some debate as to what the core components of an FRMS are, the six core components of an SMS are often cited as integral to an effective FRMS (Booth-Bourdeau *et al.*, 2005; Fletcher, 2007; ALPA, 2008; Holmes and Stewart, 2008). Subsequently, an FRMS could include:

1. Fatigue risk management policy.
2. Fatigue risk management, including collecting information on fatigue as a hazard, analysing its risk and instigating controls to mitigate that risk.
3. Fatigue reporting system for employees.
4. Fatigue incident investigation.
5. Fatigue management training and education for employees and management.
6. A process for the internal and external auditing of the FRMS.

Additionally, like an SMS, an FRMS includes an accountable manager, who is ultimately accountable for fatigue risk, and it needs to exist within a just culture in which employees and management trust one another and information about fatigue is openly reported.

While we have provided a generic overview of what constitutes an FRMS, it is important for any FRMS to be adapted to the industry, the regulatory environment and the organisation in which it applies. Consequently, there may not be a definitive and comprehensive list of FRMS components which apply in all circumstances and it may be necessary to finalise the components of an FRMS once the circumstances in which it will be developed are clear.

To determine the scope of an FRMS and the components that will be required, organisations need to conduct a risk assessment to determine the extent of their fatigue risk exposure. If fatigue is deemed to pose a low risk, for example, as operations are conducted in normal office hours and employees are not performing safety critical tasks, then simple strategies such as a documented fatigue management policy and the inclusion of fatigue in existing health and well-being training may suffice.

At the other end of the scale, the road transport industry is exposed to a relatively high level of fatigue risk. Drivers often work shifts and long hours, which promote fatigue, and driver fatigue can lead to road traffic collisions (RTCs), resulting in serious injury and loss of human life, as well as costs to the company and to society. Therefore, it can be anticipated that many road transport operators will need to implement a relatively advanced FRMS inclusive of, perhaps at least, the six core elements listed above.

4.5 What potential benefits do FRMS have?

FRMS is a relatively new strategy and only a small number of formal evaluations of FRMS in practice have been undertaken or published. The evaluations of FRMS that have been conducted are discussed in Section 5. Before analysing how FRMS has fared in practice, however, we can consider the benefits it is theoretically supposed to have over HoW limitations and isolated controls for managing fatigue.

FRMS was developed to provide enhanced protection against fatigue risk. A primary reason why FRMS is supposed to deliver enhanced protection is because it measures actual risk and establishes tailored controls to mitigate or eliminate risks. One of the main criticisms of relying on HoW limitations to provide protection from fatigue risk is that this approach involves complying with a prescribed set of rules rather than promoting the measurement and management of an organisation's unique risk exposure. In contrast, FRMS is data driven: data are collected from the operation, fatigue management decisions are made against this data, and the controls that are required can be identified and implemented. Furthermore, whereas prescriptive limitations are not backed up by science or data, the controls used as part of an organisation's FRMS can be defended because they are based on data collected from the operation itself.

By measuring actual fatigue risks and developing tailored controls within an organised safety system, an FRMS is able to identify multiple sources of fatigue and provide integrated, multiple defences against fatigue. Even if the 'perfect' set of HoW limitations could be established for an industry or organisation, they would still only address the fatigue caused by HoW. HoW limitations are incapable of protecting against the fatigue experienced by a truck driver kept awake at night by a sick child or for other non-work reasons, such as lifestyle, age or health complaints. In contrast, FRMS considers the full range of causes of fatigue and the need to apply multiple defences against fatigue risk (Dawson and McCulloch, 2005b), for example HoW limitations plus a fatigue management policy, employee fatigue reporting system and fatigue management training.

While HoW limitations are static and take a 'one size fits all' approach to fatigue, an FRMS is outcome-based and could allow for greater operational flexibility. An outcome-based approach recognises that there are many different means via which the same outcome (managing fatigue) can be achieved in different situations and within different organisations. As such, FRMS allows flexibility in how fatigue and its risks are managed.

In some cases, this could imply greater operational flexibility. Accordingly, a regulator would allow an operator greater flexibility in HoW rules – for example, by granting an alleviation to standard HoW limitations which means that the organisation can work longer hours. This flexibility in HoW occurs in recognition that the company will be able to manage its HoW as part of a broader, and theoretically safer, risk management process. In contrast to a prescriptive approach, HoW are treated as one of the many risks of which the company should take ownership in order to manage safety effectively.

An additional weakness identified with the prescriptive approach is that operators are not encouraged to manage fatigue risk; compliance with HoW limitations is usually sufficient. Under outcomes-based regulation and FRMS, however, operators (management and employees jointly) take responsibility for managing fatigue risk. Although regulators provide guidance and ensure FRMS are audited, the ultimate responsibility for fatigue lies with the operator.

By approaching fatigue management in a systematic and documented way, FRMS also avoids one of the primary criticisms of the use of isolated fatigue management strategies, such as training and education, namely, that they are often sporadic, haphazard and isolated. Modelled on SMS, FRMS is intended to be an organised and business-like approach to fatigue risk management, and the design and operation of the FRMS should be recorded and documented.

A last theoretical benefit of an FRMS is that it is intended to be proactive and reactive. As explained in Section 3.5, conventional controls for fatigue risk tend to be implemented reactively, when a fatigue-related incident or accident occurs. An

FRMS is reactive as it stipulates that an incident should be investigated to identify its causes and to establish effective controls against it repeating. However, it is also proactive as controls are developed for addressing the root causes of fatigue in the operation before an incident has occurred.

4.6 Summary – what is an FRMS?

- An FRMS can be defined as a scientifically-based, data-driven addition or alternative to prescriptive HoW limitations which manages employee fatigue in a flexible manner appropriate to the level of risk exposure and the nature of the operation.
- FRMS and SMS are examples of the regulatory move from prescriptive standards to outcome-based regulations.
- As part of an SMS, FRMS is an organised, systematic and documented approach to managing fatigue risk which needs to exist within a just safety culture.
- An FRMS might consist of (but need not be limited to):
  1. a fatigue policy;
  2. risk management focused on fatigue;
  3. fatigue reporting;
  4. incident investigation;
  5. fatigue awareness and countermeasures training and education; and
  6. auditing.
- Theoretically, an FRMS could provide enhanced protection against fatigue risk compared with HoW limitations and isolated strategies for managing fatigue because:
  - FRMS is data-driven, measures actual risks and develops tailored controls;
  - multiple causes of fatigue and defences against fatigue are considered;
  - FRMS enhances flexibility;
  - responsibility for managing the risk of fatigue rests with the operators;
  - FRMS is a systematic and documented approach to fatigue management; and
  - FRMS is proactive and reactive.

5 THE EVOLUTION AND EVALUATION OF FATIGUE RISK MANAGEMENT SYSTEMS

5.1 Introduction

Road transport and aviation regulatory authorities in Australia and New Zealand were the first to trial Fatigue Risk Management Systems (FRMS) as an alternative method for operators to manage fatigue risk. This section describes the four trials that have been formally documented and evaluated (Burgess-Limerick and Bowen-Rotsaert, 2002; McCulloch *et al.*, 2003; Signal *et al.*, 2006; Denton, 2007).

Section 5 is structured as follows:

- Section 5.2 provides an overview of the four FRMS trials.
- Sections 5.3 to 5.6 consider each of the trials in chronological order, based on when they were first initiated.
- Section 5.7 summarises a review of fatigue management programmes conducted for Transport Canada.
- Section 5.8 discusses the components of FRMS in the trials and provides tables comparing the advantages and disadvantages of FRMS as highlighted by the evaluations of the trials.
- Section 5.9 provides recommendations for regulators regarding the development and implementation of FRMS.
- Finally, Section 5.10 summarises the main points arising from Section 5.

5.2 Overview of the four FRMS evaluations

In order to provide an overview of the four FRMS trials that have been evaluated to date, this section contains two central tables: Table 5.1, which summarises the structure of each trial, and Table 5.2, which summarises the research methodology that was used to evaluate them.

Two of the FRMS trials were initiated by road transport authorities: Queensland Transport (Australia) and the Land Transport Safety Authority (New Zealand), while the other two were conducted by the Australian and New Zealand aviation regulators (CASA and CAA NZ, respectively). The principal aim of the road transport and Australian Aviation trials was to assess the potential value of FRMS and to inform the decision whether to use this approach more broadly. The New Zealand Aviation study was different because the regulator had enabled operators to put in place an alternative fatigue management scheme. The primary aim of this evaluation was to identify how fatigue was actually being managed by operators.

Table 5.1: Details of the four FRMS trials

Title	Fatigue Management Programme (FMP) trial	CAA NZ scheme	LTSA trial	CASA trial
Regulator	Queensland Transport: Road Haulage	CAA NZ: Aviation	LTSA: Road Haulage	CASA: Aviation
Date initiated	1994	1995	2000	2001
Operators	Road freight – type unknown	General aviation and large airlines	Variety of road freight including refrigerated produce and dangerous goods	General aviation
FRMS audit requirements	10 fatigue management standards:	Required elements:	Fatigue management standards:	An FRMS should include:
	1. Scheduling of trips and rostering of drivers should take fatigue into account.	1. The identification and assignment of responsibilities.	1. Operators are required to prove that they are committed to fatigue management and they need to ensure that the relevant staff are aware of their delegations, responsibilities and duties for fatigue management.	1. Responsibility – management's commitment to managing fatigue, and the responsibilities for fatigue of both management and employees should be clearly detailed.
	2. Operating limits need to provide enough flexibility for fatigue to be effectively managed.	2. Ongoing education of management and staff.	2. All staff involved in the FRMS should be provided with relevant training.	2. Education and training – all management, aircrew and operations employees need to be provided with fatigue management training.
	3. Readiness for duty – drivers are required to be fit to safely perform their duties.	3. A fatigue and incident/ accident reporting and investigation system.	3. Operators and drivers need to ensure that drivers are fit for duty.	3. Rostering – aircrew rosters should be analysed using fatigue modelling software.[7]
	4. Health – All drivers are required to participate in a health management system which will help to identify and manage fatigue risks.	4. Workload monitoring – the influence on fatigue of, for example, meteorological conditions, the type and density of traffic and circuit patterns need to be considered.	4. Operating limits, scheduling and rostering should incorporate fatigue management controls.	4. Fatigue reporting system – employees should be encouraged to report occurrences of fatigue which will be analysed by the company.

	5. Management practices need to ensure drivers are appropriate for the freight task and they should support effective communication between management and drivers on safety.	5. The identification and management of fatigued personnel.	5. Workplace conditions should help to manage fatigue effectively.	5. Internal audit – the FRMS needs to be reviewed annually in order to identify ways in which its function can be improved.
	6. Workplace conditions should help to prevent fatigue through, for example, the provision of suitable sleeping conditions.	6. System review – '[T]he scheme should contain a monitoring system with a provision for regular reviews of the scheme by management and flight crew. This review should provide the assurance that the scheme is effective and is achieving the desired outcomes' (CAA NZ, 2007: 34).		
	7. Training and education on fatigue management should be provided for all relevant staff.		Note, the FRMS also requires internal auditing, an incident investigation procedure, and allows for external audits by the regulator to monitor compliance and investigate complaints.	
	8. Responsibilities – all relevant staff need to be made aware of their responsibilities for managing fatigue risk.			
	9. Records and documentation – documented policies and procedures for effective fatigue management need to be established and reviewed. Records concerning the operation of the FMP need to be identified, collected, stored and maintained.			
	10. Internal review – compliance with the FMP standards should be checked through an internal auditing system.			

7 As explained in Section 3, fatigue modelling software uses algorithms to predict the fatigue caused by working hours.

Table 5.2: Details of the trial evaluations

Title	**FMP trial**	**CAA NZ scheme**	**LTSA Trial**	**CASA Trial**
Regulator	Queensland Transport: Road Haulage	CAA NZ: Aviation	LTSA: Road Haulage	CASA: Aviation
Aim	Compare fatigue in FMP to non-FMP	Identify how fatigue is being managed	Evaluate performance of FRMS	Evaluate performance of FRMS
Assessment report	Burgess-Limerick and Bowen-Rotsaert (2002)	Signal *et al.* (2006)	Gander *et al.* (2008)	McCulloch *et al.* (2003)
Data collection	(1) Driver survey (2) Business survey	Survey	(1) Driver survey (2) Sleep diary (3) Business survey	(1) On-site visit (2) Interview (3) Questionnaire (4) Document review
No. of companies participating in study	8–9	88	9	16
Role of participants in study	• Drivers • Managers	• Flight crew • Managers • Dispatchers	• Drivers • Managers • Dispatchers	• Flight crew • Managers • Dispatchers
Results of study	Overall positive for FRMS	Operators not implementing FRMS	Trial discontinued	Overall positive for FRMS

The evaluations largely collected subjective data via interview and questionnaires of employees and managers. This approach has provided valuable data on subjective opinions, advantages, disadvantages and issues regarding implementation. However, subjective data should be treated with some caution as there is a potential for bias and the influence of industrial negotiations relating to pay and work hours. Lifestyle, for example, could have improved due to new roster patterns, while fatigue was not improved. Although the results of the evaluations were largely positive, and there was some anecdotal evidence of a reduction in accidents, in the absence of objective safety data it is not possible to conclude that FRMS is associated with improvements in safety.

5.3 Queensland Transport Fatigue Management Programme trial

5.3.1 Overview of the FMP

In 1994, Queensland Transport (the Department for Transport of the Australian state of Queensland), together with representatives from the road transport industry, commenced the first pilot of a 'Fatigue Management Programme' (HRSCCTA, 2000). In order to be accredited and to operate outside of the standard HoW limitations, companies participating in the trial had to be able to demonstrate that they met 10 'fatigue management standards' (see Table 5.1). Operators were required to provide evidence for how they met these standards in the form of policies, procedures, auditing and evaluation systems (Burgess-Limerick and Bowen-Rotsaert: 2002; Nolan, 2005).

5.3.2 Evaluation methods

The Queensland Transport FMP trial was assessed by Burgess-Limerick and Bowen-Rotsaert (2002).[8] The researchers surveyed road transport businesses and drivers to measure and compare driver fatigue and business outcomes under FMP conditions and under non-FMP conditions (i.e. compliance with standard HoW limitations).

Surveys were administered in three waves over a six-year period between 1996/97 and 2001/02 (Table 5.3). The first survey wave collected data from nine companies and their drivers. Some of the nine companies implemented an FMP and, although it is not explicitly stated in the report, it seems probable that these and their drivers were subsequently surveyed again in waves 2 and 3. The authors do not provide data on the size of the companies involved in the study, but they do mention that 94% of the FMP drivers in wave 2 were from one company and 70% of FMP drivers in wave 3 were from one company. Thus, it appears that most FMP drivers who participated in the evaluation worked for the same company.

8 This is the only report publicly available, but Burgess-Limerick and Bowen-Rotsaert comment that other independent assessments of the FMP trial were conducted.

In order to compare data from the FMP companies with data from companies not working under FMP, 'industry comparison' companies and drivers were surveyed in waves 2 and 3.[9]

Table 5.3: Details of the survey respondents

Survey	Dates	Who completed the surveys?	
		Drivers	**Companies**
Wave 1 (baseline)	July 1996 to April 1997	248 truck drivers (42%)	9 potential FMP companies
Wave 2	May 2001 to January 2001	101 FMP drivers (34%)	5 FMP companies
		21 industry comparison drivers (20%)	3 industry comparison companies
Wave 3	January 2002 to March 2002	82 FMP drivers (27%)	6 FMP companies
		31 industry comparison drivers (86%)	2 industry comparison companies

The driver fatigue survey consisted mainly of multiple-choice questions aimed at:

- developing a profile of the driver;
- determining how individual trips are planned and scheduled;
- determining the driver's level of understanding, identification and management of fatigue;
- determining driver involvement in rostering; and
- developing a profile of driver lifestyle and its impact on fatigue management.

The business survey mostly consisted of open-ended questions regarding the participating companies' current fatigue management practices and, where relevant, their experiences of the FMP. Data were collected, for example, on:

- how scheduling and rostering are determined;
- the benefits and difficulties of FMP;
- the impact of the FMP on efficiency (e.g. through truck utilisation and customer satisfaction);
- operating profits; and
- the cost of implementing and operating the FMP.

9 It is not clear if these companies and drivers are a sub-population of the initial baseline group (surveyed in wave 1), or whether the same individuals were surveyed in waves 2 and 3.

The results of the study may not be representative. As mentioned, many of the drivers surveyed under FMP conditions belonged to the same company. Additionally, the response rates to the surveys varied widely between waves and also between those working under FMP and non-FMP conditions. Furthermore, the authors themselves note that, in addition to large differences in sample size, there is the potential for bias in the industry comparison group (Burgess-Limerick and Bowen-Rotsaert, 2002). The very fact that the comparison group responded to the survey suggests that they may have been particularly aware of, and likely to address, fatigue-related issues and thus may not be representative of the broader industry.

5.3.3 Reported advantages of the FMP

Overall, companies involved in the FMP reported that it had a positive effect. 'Most' companies reported that the FMP had a positive effect on business efficiency 'as measured by truck utilisation, customer satisfaction, fatigue related accidents, and driver turnover' (Burgess-Limerick and Bowen-Rotsaert, 2002: 22).

Additionally, they listed a number of advantages that the FMP held for their business. In response to the open-ended question 'What benefits does the FMP have for the company?' all of the six FMP companies reported that the FMP was effective in reducing driver fatigue. Other reported benefits (the exact number of companies who reported each benefit of the FMP is not explicitly stated) included:

- added flexibility in scheduling and driver management;
- greater utilisation of drivers as they are better rested;
- legal operations;
- drivers who are better able to manage fatigue;
- reduced driver fatigue;
- reduced risks;
- reduced legal exposure;
- lower costs; and
- improved record-keeping which helps to determine business viability.

Additionally, the authors of the evaluation reported that drivers working under FMP conditions 'are exposed to significantly less fatigue-related risk' (Burgess-Limerick and Bowen-Rotsaert, 2002: 3). This conclusion was based largely on a statistical comparison of responses to multiple-choice questions about scheduling and fatigue, (e.g. 'How often do you feel tired, or have difficulty concentrating, while driving?'), given by drivers working under FMP conditions and non-FMP conditions. However, as the authors noted, 'the differences between the groups cannot be ascribed to working under FMP conditions alone' (Burgess-Limerick and Bowen-Rotsaert, 2002: 30). Over the course of the three survey waves, the level of 'fatigue-related risk' reported by drivers decreased amongst both the FMP drivers and the industry comparison drivers, suggesting that changes in industry over time and factors other than fatigue management influenced the end results.

5.3.4 Reported disadvantages of the FMP

When asked 'What difficulties have you experienced in implementing the FMP?', driver 'buy-in' was mentioned by a number of the companies involved (exact number not given). Companies reported difficulties in gaining driver understanding and commitment to the FMP, initial driver negativity, and changing driver culture and getting drivers to do the training and the medicals. Convincing drivers of the benefits of the FMP required addressing their concerns that: (1) the FMP would be economically disadvantageous for them, and (2) the company would be working them harder under FMP conditions.

Other reported difficulties included:

- the need to standardise the rosters and schedules between the different Australian states;
- conflict between existing enterprise bargaining and the FMP model;
- industrial disharmony;
- explaining the FMP to other operators;
- an initial increase in administrative workload and paperwork;
- a lack of knowledge by enforcement officers; and
- a conflicting FRMS.

The initial implementation of an FMP may have particular problems which are ironed out over time, or are only applicable on implementation. To explore whether the continued maintenance of an FMP provides additional difficulties, companies were asked 'What difficulties have you experienced in operating under FMP?' The difficulties companies reported include:

- a lack of knowledge by enforcement officers;
- human error in auditing hours and the time-consuming nature of the audit;
- drivers' desire to work extra shifts; and
- the time-consuming nature of the ongoing education of drivers and schedulers.

5.3.5 *Costs of the FMP*

Companies were also asked to detail the costs of the initial implementation of the FMP programme and of maintaining it once it had been implemented. Table 5.4 summarises the costs in Australian dollars (A$), most of which were associated with training, administration and auditing. The average cost of operating the FMP was A$659 per driver per year, but was reported by one company as A$4,100 per driver per year. However, this company had comparatively fewer drivers than other participating companies, and the figure included the operating costs for other management systems that had also been implemented.

Table 5.4: Costs of implementing and operating FMP (*n* = 4)

Cost of implementing and operating	**Average cost**	**Range of costs**
Implementation of FMP		
Total implementation cost	A$43,100	A$22,000-A$80,000
Cost per driver	A$681	Not reported
Operation of FMP		
Total operating cost	Not reported	Not reported
Cost per driver	A$659/year	Max: A$4,100/year (other management systems included)

5.3.6 *Discussion*

In conclusion, participating operators reported that the FMP was effective in reducing driver fatigue and were positive about the impact of the FMP on their operations. However, as the study might not be representative, the findings have to be treated with caution. Nonetheless, the study provided some valuable feedback from participants, which could be useful in understanding the advantages and disadvantages of FRMS.

The trial does not seem to have had any pre-defined end date and at least one company continued operating under the trial conditions after the assessment of the trial was completed (Nolan, 2008: personal communication). To some extent this trial also contributed to the new heavy vehicle driver fatigue legislation which came into effect in September 2008 (see Section 6), which will give all operators in Australia the opportunity to develop FRMS in exchange for flexibility in HoW.

5.4 CAA NZ alternative compliance scheme

5.4.1 Overview of the alternative compliance scheme

Since 1995, the Civil Aviation Authority of New Zealand (CAA NZ) has allowed aviation operators to apply to work under an 'alternative fatigue management scheme', essentially by implementing an FRMS, rather than prescriptive flight and duty time limitations (Signal *et al.*, 2006). An operator's FRMS must include detailed documents and policies demonstrating compliance with the required elements listed in Table 5.1. Operators working within the alternative scheme must also define and monitor their own fixed limits for flight, duty and rest periods (CAA NZ, 2007).

5.4.2 Evaluation methods

In 2006 the Sleep/Wake Research Centre at Massey University was awarded a grant under the Australian Government's Aviation Safety Research Grants Program to evaluate how fatigue was being managed by the aviation operators using the alternative scheme (Signal *et al.*, 2006; Signal, 2009: personal communication).

At the beginning of the project, an industry working group consisting of representatives from the New Zealand regulator, unions and industry was established to help with the design of the evaluation. Initially the project was intended to focus on how FRMS, defined as 'multi-faceted approaches that incorporate recent scientific findings', were being implemented (Signal *et al.*, 2006: 4). However, after consulting the industry working group, the researchers found that very few operators working under an alternative management scheme were actually using a genuine FRMS, rather than prescriptive rules. Thus the focus of the evaluation changed: its new aim was to establish how fatigue was being managed by those operating within the alternative scheme and by others working to the normal flight and duty time limitations.

As part of the study, questionnaires were sent to all aviation organisations in New Zealand who carry 'passengers or goods for hire or reward' (Signal *et al.*, 2006: 6). Three questionnaires were sent to each organisation with one addressed to a manager, one to a rostering officer, and the third to a line pilot. A response rate of 52% was recorded and 153 questionnaires were completed by individuals from 88 organisations.

The questionnaire consisted of three main sections:

- description of the organisation, for example the type of aircraft the company operates;
- fatigue management strategies in the organisation, for example multiple-choice type questions on whether the company uses ongoing fatigue education as part

of its fatigue management strategies; and

- how well fatigue management works in the organisation, for example open-ended questions on the benefits of fatigue management.

5.4.3 Fatigue management strategies

Respondents were provided with a list of 10 fatigue management strategies and were asked to identify which of these their organisation used to manage fatigue (Table 5.5). The most important finding was that companies who were supposed to be operating according to an alternative compliance scheme had no more fatigue management strategies in place than other companies. Indeed, few companies within the scheme seemed to be genuinely using an FRMS and were still largely relying on the standard prescriptive flight and duty time limits.

Overall, small aircraft operators were less likely to use fatigue management strategies than operators of medium or large aircraft. Sixty per cent of large and medium operators reported having eight or more fatigue management strategies in place, whereas only 28% of helicopter and small aircraft operators reported having eight or more. However, some individual strategies went against the trend; for example medium operators (100%) were much more likely than large operators (60%) to identify and manage fatigued personnel.

Table 5.5: Percentage of organisations that reported using various fatigue management strategies (note, the number of responses for each cell was not reported)

Fatigue management strategy	Large (> 30 passengers) aircraft operators (%)	Medium (10–30 passengers) aircraft operators (%)	Small aircraft (< 10 passengers) or helicopter operators (%)
Monitoring flight and duty times	90	90	99
Feedback system	90	80	66
Reporting system that includes fatigue	80	70	44
Monitoring workload	70	90	84
Pilot education	70	70	53
Rostering software	70	50	23
Management education	50	70	43
Rostering staff education	50	50	36
Identification and management of fatigued personnel	60	100	68
Review of processes for managing fatigue	60	60	39

Despite large and medium operators reporting that they had many fatigue management strategies, the assessment found that, in general, operators did not understand or manage fatigue well. When asked to provide examples of fatigue management strategies, respondents often struggled to find examples, or they provided examples which demonstrated a lack of knowledge of fatigue and good fatigue management. For example, when asked what their fatigue management training consisted of, some companies reported that it was focused on describing flight and duty time limitations, and when asked to provide examples of fatigue management strategies at their company, the person responsible for fatigue management was identified, but the respondents but did not know what the strategy was. Furthermore, a number of companies reported that they did not need information on fatigue management or that they managed fatigue using 'common sense'.

5.4.4 Reported advantages

In the questionnaires, respondents were asked to list the advantages and disadvantages of their company's fatigue management strategies. The perceived advantages were (numbers not provided):

- improved safety;
- improved pilot performance;
- improved pilot productivity;
- improved pilot mood;
- improved fatigue awareness;
- greater flexibility in pilot use; and
- prevention or earlier intervention.[10]

5.4.5 Reported disadvantages

Most respondents indicated that there were no negative aspects of their fatigue management strategies. Those who reported negative aspects described the following disadvantages (numbers unknown):

- loss of flexibility;
- difficult to manage;
- limited staff numbers;
- not detecting pilots are fatigued;
- present approach to fatigue management not sufficient;
- costs; and
- no education (i.e. some pilots reported that their company had not educated them about fatigue management).

10 Respondents who identified this strength reported that fatigue management strategies are able to prevent fatigue occurring or had made them able to intervene earlier in a situation where fatigue might become a problem.

5.4.6 *Discussion*

The most important finding from the evaluation was that many of the companies who were operating according to an alternative compliance scheme did not have FRMS, or any more strategies than other companies. In addition, many companies who claimed to be managing fatigue felt that 'common sense' was sufficient and did not have an understanding of what was required of them.

Signal *et al.* (2006) suggest that the regulator could have provided better guidance on how to develop an FRMS. They recommend the following:

- Comprehensive information should be provided for managers on fatigue (information should be easily accessible and/or provided through industry seminars).
- Detailed information should be provided on how to develop and implement an FRMS.
- Educational and training packages for staff, which an organisation could tailor easily to their operation (again also easily accessible).
- On-going publications and articles in industry magazines.
- A dedicated internet site or page where information and examples can be easily accessed.

A further important result of the evaluation is that smaller companies tend to engage less in fatigue management than medium or larger operators. Potentially, they do not have the same access to resources as medium and large companies to develop enhanced fatigue management. Consequently, differences in the size of operators should be taken into consideration by a regulator interested in enhancing fatigue management.

Currently, it appears that NZ aviation operators are still able to implement alternative schemes. In 2006, CAA NZ held a fatigue workshop which identified a number of areas within the rules, advisory circulars and educational material on fatigue that required updating (CAA NZ, 2008). As a result, a Fatigue Risk Management Project Group was set up to implement the recommendations of the workshop.

5.5 Land Transport Safety Authority trial of FRMS

5.5.1 *Overview of the FRMS trial*

The third trial of FRMS was initiated in 2000 by the Land Transport Safety Authority (LTSA)[11] of New Zealand (Denton, 2007; Gander *et al.*, 2008). However,

11 The LTSA was renamed Land Transport NZ during the trial and is now known as the NZ Transport Agency.

due to changes in LTSA staff, the trial proper did not commence until 2006, when invited companies wishing to participate were provided with training on fatigue and its management (Denton, 2007). The trial was supposed to inform new regulation, but the delay in the implementation meant it was overtaken by changes to the prescriptive work limits applicable from October 2007, which included a provision to allow companies to develop FRMS (Denton, 2007; Gander *et al.*, 2008). As a consequence, the trial became unnecessary once the new regulations had been introduced. Despite being discontinued, it is useful to look at the study to understand how FRMS was experienced and what can be learnt from the design of the trial.

Nine operators, responsible for transporting a variety of goods, ranging from refrigerated produce to dangerous goods, were invited to participate in the trial (Gander *et al.*, 2008). Drivers in the trial would be 'exempt from working within the regulated maximum work time limits in the legislation' (Land Transport NZ, 2008: 6).

In common with the Queensland Transport trial, operators submitted their own FRMS to the LTSA for audit according to five fatigue management performance standards (Table 5.1; Land Transport NZ, 2007). If the FRMS was approved, operators were 'exempt from working within the regulated maximum work time limits in the legislation' (Land Transport NZ, 2008: 6).

5.5.2 Evaluation methods

Before the trial was discontinued, the Sleep/Wake Research Centre at Massey University collected baseline data from managers, dispatchers and drivers at the nine participating companies through questionnaires and sleep/wake diaries (Gander *et al.*, 2008). The data were analysed and reported with a focus on 'identifying areas that could be better managed to reduce driver fatigue risk, either under an FRMS or working under the prescriptive work hours regime' (Gander *et al.*, 2008). As the results do not provide any data on experiences under FRMS, they will not be discussed in this report.

5.5.3 Discussion

Perhaps the key piece of information to take from the trial is the researchers note that the trial would have benefitted from the involvement of more companies and drivers. A large number of drivers who had completed the initial survey for the scientific evaluation of the trial left their companies, making the continued evaluation of the trial challenging, and thus contributing to its discontinuation (Gander *et al.*, 2008).

Other lessons that can be learnt from the trial include (Denton, 2007):

1. The initial process set up for companies to develop an FRMS was too complex and difficult.
2. Fatigue management should not be isolated from the day-to-day activities of a company. An FRMS needs to be incorporated 'into most of the activities that good companies undertake – e.g. health and safety policies, training and accident/incident investigation should all incorporate fatigue as an issue that needs to be considered' (Denton, 2007: 8).
3. It is difficult for both operators and the regulator to assess the acceptability of an FRMS. In the trial, operators had to present an FRMS to the regulator for approval. However, neither party felt confident about being able to evaluate the risks associated with their FRMS.
4. The biggest challenge identified was trying to capture 'each set of operating limits and countermeasures onto an A5-sized "approval notice" that could be issued to each driver operating under the FRMS, and which could be easily used for roadside enforcement' (Denton, 2007: 8).

5.6 Civil Aviation Safety Authority FRMS trial

5.6.1 Overview of the CASA trial

The final FRMS trial can be traced back to October 2000, when the House of Representatives Standing Committee on Communication, Transport and the Arts (HRSCCTA) released a report on fatigue in the aviation, maritime, road and rail transport industries in Australia (HRSCCTA, 2000). One of its recommendations was that the Civil Aviation Safety Authority (CASA) of Australia 'should implement a Fatigue Risk Management System to regulate flight and duty times for aircrew' (HRSCCTA, 2000, p.41).

At the time of the report, the flight and duty times of flight crew were prescribed by Civil Aviation Order Part 48 (CAO 48) (HRSCCTA, 2000). A number of exemptions were granted to companies who claimed that CAO 48 was too restrictive for their operations. Exemptions became controversial as many of them were not based on safety cases, their impact was not evaluated and they became the norm – most operators were working to the exemptions, rather than to the limits of CAO 48 (HRSCCTA, 2000; CASA, 2004).

In response to the recommendations of the report and their own attempts to develop an alternative to CAO 48, CASA cancelled many CAO 48 exemptions and in 2001 initiated a trial of FRMS involving 21 general aviation operators from across Australia (McCulloch *et al.*, 2003; CASA, 2004). Operators participating in the trial were required to present a safety-based case to CASA demonstrating how they would manage fatigue risk effectively and why operating under CAO 48 was too restrictive for their operations (CASA, 2004).

Details of the instructions provided to operators at the beginning of the trial explaining what an FRMS should consist of were not available.[12] However, an example FRMS template released by the regulator during the trial stipulates that an FRMS should include the elements listed in Table 5.1 (McCulloch *et al.*, 2003).[13] This trial incorporated five of the six main elements of an FRMS (see Section 4.4) with the only omission being an explicit requirement for risk management.

CASA commissioned the Centre for Sleep Research at the University of South Australia to assess the trial (McCulloch *et al.*, 2003). The aim of the assessment was to determine whether FRMS was a viable alternative to the prescriptive legal limits (CAO 48).

5.6.2 Evaluation methods

McCulloch *et al.* (2003) report that 16 of the 21 general aviation operators who were trialling FRMS participated in the evaluation of the trial. Management were approached by email and a follow-up phone call to determine whether they were interested in participating in the evaluation. The five operators who did not participate cited the costs of participating and a lack of availability of relevant staff as reasons why they chose not to participate.

Data were collected using four methods:

1. Onsite visits – during the onsite visits, an evaluator conducted interviews, administered the questionnaires, collected documents and made observations.
2. Interviews with key stakeholders – relevant employees, including rostering staff and flight crew, were interviewed during the onsite visits. The interview consisted of general questions about the FRMS (e.g. 'What do you see as the major strengths of the FRMS?') and more specific questions about individual components of the FRMS.
3. Questionnaires – interviewees were also asked to complete questionnaires consisting of five-point Likert-scale questions during the interviews. For example, interviewees were asked, 'How would you rate your overall satisfaction of the FRMS?', and were provided with the options: 'Very Good', 'Good', 'Average', 'Poor' and 'Very poor'.
4. Document review – all relevant documentation related to the FRMS of each individual operation was collected and analysed.

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12 In the evaluation report of the trial, McCulloch *et al.* (2003) describe the basic components of which an FRMS should consist. However, this seems to be the authors' description of an FRMS rather than CASA's explanation of what operators participating in the trial should include as part of their FRMS.

13 The FRMS template was provided merely as an example and operators were free to develop their own FRMS as long as it complied with the elements listed in Table 5.1.

Although some observations were made and documents were reviewed, overall the data collected were subjective.

Figures were provided for the number of operators who participated in the study, no details are available on the number of participants at each operator or the total number of employees that participated in the FRMS trial. However, based on the interview transcripts, it appears that 17 flight crew and 17 managers, including chief pilots, were interviewed.

5.6.3 Reported advantages of FRMS

Overall, participants responded positively to FRMS – 90% of managers and 85% of flight-crew reported that FRMS had a 'positive impact on operations' (McCulloch *et al.*, 2003).

The reasons why the participants felt that FRMS had a positive impact on operations are similar to the advantages of FRMS that they identified. To collect information on the perceived advantages of FRMS, management and flight crew were asked the open-ended question 'What do you see as the major strengths of the [FRMS]?' in the interviews. The most commonly cited advantages were:

- An increased awareness and understanding of fatigue that has resulted in a perceived increase in safety – instead of simply having to comply with prescriptive limits, employees are better able to understand why it is important to be concerned about fatigue and what countermeasures can be used to address fatigue.
- Operational flexibility – employees can work longer or shorter hours than the prescriptive limits of CAO 48 as long as they are fit for duty and roster analysis shows that their duties are acceptable from the perspective of fatigue.
- Increased productivity – operators are able to schedule pilots more effectively and this has led to increased productivity and more efficient business operations.
- FRMS is less complex and easier to use than CAO 48 – operators reported that data entry, for example, was less time-consuming and less complex calculations were required for rostering.
- Clearer sharing of responsibility relating to fatigue – the responsibilities for fatigue are clearly set out and include responsibilities for the management, the flight crew and the regulator.
- Fatigue modelling provides a scientific basis for fatigue management – both management and flight crew felt that the fatigue modelling software they were using had a strong scientific background. As discussed in the next section, however, there were problems with the way in which fatigue modelling software was used.

5.6.4 Reported disadvantages and problems of implementation

When asked the open-ended question, ‘What do you see as the major weaknesses of the [FRMS]?’, the following six weaknesses were most commonly identified:

- Operators reported problems with fatigue modelling software (see Section 3.4) – for example, they expressed doubts about the reliability and validity of fatigue modelling and they claimed that fatigue modelling was often used as an FRMS, instead of one of many tools which could form part of an FRMS.
- Both managers and flight crew reported concerns that the FRMS has the potential to be abused. For example, some pilots were concerned that the FRMS would mean that management would be able to make them work longer hours or a greater number of shifts.
- A few organisations reported that the FRMS had decreased the amount of hours the flight crew were able to work and this had decreased productivity.
- Operators also reported an increased workload in setting up and maintaining the FRMS, particularly in terms of policy writing.
- With FRMS, responsibility shifts from the regulator to the operator. Some operators were unhappy with the increased potential for legal liability.
- Operators were concerned with the absence of risk assessment in the FRMS. They reported that the FRMS did not consider the risks associated with different tasks, for example, the difference between an office duty and a flying duty.

McCulloch *et al.* (2003) reported that some of the other perceived weaknesses of FRMS were problems in implementation rather than actual disadvantages of FRMS. For example, they claim that perceptions of higher workload and the complexity of FRMS could be attributed to the lack of resources and guidance provided by the regulator. This would have been a problem particularly for operators who participated from the beginning of the trial period, as they would have received less information from CASA than those who started at a later date in the process. This could explain why some operators believed, for example, that an FRMS was more complex than CAO 48, while others believed that it was less complex.

Overall the evaluation found that operators supported FRMS, however, the authors of the evaluation were critical of how FRMS had been implemented. They summarise the problems with the implementation of the FRMS as follows:

- FRMS was a new approach and there was a lack of understanding of the costs and resources necessary for it to be effective. Neither the regulator nor the industry fully understood how to go about developing, implementing and operating an FRMS.
- The regulator provided too little guidance and the guidance provided was misused. A major finding of the evaluation was that organisations were confused

about how to develop an FRMS and reported that the regulator had not provided them with clear guidelines on how to develop and implement an FRMS. In response to the demand for more guidance, CASA released a policy template for FRMS called ‘Company Sky One’, which aviation operators could use to help them develop their own policy. Many operators, however, simply copied this template into their own policy document and presented it back to the regulator as their FRMS.

- The transition from a prescriptive to an outcome-based culture is difficult. Both the regulator and the operator were used to a prescriptive ‘tick and flick’ system of compliance. Moving from this culture to an outcome-based culture requires substantial changes in attitude and policy.

5.6.5 Discussion

Overall, the evaluation of the CASA FRMS trial showed positive results based on mainly subjective data. The majority of management and flight crew were positive about the impact that FRMS had on their company. The perceived disadvantages and problems of implementation identified with FRMS are especially useful in helping to inform the design of future FRMS trials. For example, a weakness of the trial was that operators were copying the example FRMS provided by the regulator instead of developing their own FRMS. An FRMS should be adapted to an operator’s actual risks, thus an FRMS that is copied straight from another organisation is unlikely to be successful. As McCulloch *et al.* (2003: 9) point out, ‘using a universal template worked against the primary aim of [FRMS], which was to move away from an “all encompassing” prescriptive legislation to an operationally specific model’.

The evaluation report provided an extensive list of recommendations for CASA to help resolve the problems encountered with implementing FRMS. Among these recommendations, the following were highlighted as most significant (McCulloch *et al.*, 2003):

- The regulator should provide operators with clear guidelines and information about FRMS before implementation.
- The regulator needs to make operators aware of the nature of an FRMS, how it will benefit them, and what the regulator’s expectations are, should they choose to proceed with the FRMS.
- The regulator should ensure that each operator fully understands what fatigue modelling software can and cannot be used for.
- The regulator should ensure that each operator fully understands all of the required risk assessment steps.
- The regulator should formulate an industry toolbox, providing operators with several options of templates on which to base their FRMS to suit their operational needs.

In August 2004, after the assessment of the trial was published, CASA released a discussion paper on FRMS. The aim of the discussion paper was to provide information on FRMS ‘as an alternative to current prescriptive flight and duty times as legislated in CAO 48, for consideration and comment by interested parties’ (CASA, 2004). What feedback operators provided in response to the discussion paper is not known.

As part of this literature review, CASA were contacted and asked to provide feedback on the trial. A CASA representative responded with the following comments:

- On the whole, the trial was of interest to CASA and provided worthwhile information that has been used in follow-on project work.
- Concern was expressed about trial participants’ exclusive use of one fatigue modelling software programme. Understandably, CASA does not wish to be seen to endorse one fatigue model and has plans to release guidance material on a range of fatigue modelling approaches in the future.
- Concern was also expressed regarding the failure to assess the impact of the FRMS on safety (whether perceived or objective).

New draft regulations for managing fatigue are likely to be released by CASA for public comment in 2009 (CASA Representative, 2009; personal communication).

5.7 Transport Canada’s review of Fatigue Management Programmes

In addition to the four field-based FRMS trials described in the previous sections, Rhodes *et al.* (2005) have conducted a desk-based review of 21 fatigue management programmes that were identified through the literature. The aim of the review was to assist Transport Canada, the regulatory authority for the transport industry in Canada, to develop a manual of guidelines on FRMS for the Canadian transportation industry, based on best practice. The review considered a broad range of programmes that were designed to address fatigue, some of which consisted simply of a training programme, rather than an FRMS *per se*.

The programmes were rated according to how well they complied with five assessment criteria:

1. Flexibility, ‘i.e. can the approach be tailored and improved over time as circumstances in the company change’.
2. Policy-driven, ‘i.e. does the approach provide a means for companies to commit to managing risk’.

Table 5.6: **Summary of Transport Canada's evaluation of fatigue management programmes**

Programme name	Developing agency	Flexible	Policy-driven	Risk-based	Account./audit	Comprehensive	Overall
FRMS	CASA (Australia)	3	3	3	3	3	**15**
FMP Canadian Marine Pilots	Transportation Development Centre (Transport Canada)	3	2	3	2	3	**13**
CANALERT	Railway Association of Canada (RAC)	3	3	2	2	3	**13**
Crew Endurance Programme	US Coastguard	3	3	2	2	3	**13**
FM for Commercial Vehicle Drivers	Western Australia Commission for OHS	3	3	2	2	2	**12**
Integrated Shipboard Alertness Management	US Navy	2	3	1	3	2	**11**
Queensland Transport FMP	Queensland Transport, Australia	3	2	1	2	3	**11**
FreightCorp FMP	FreightCorp, Australia	3	3	1	2	2	**11**
FMP – NSW Rail	Transport NSW (New South Wales, Australia)	2	2	2	2	2	**10**
National Road Transport Commission Transitional FMS	National Road Transport Commission (Australia)	3	2	1	2	2	**10**
Part 395 Federal Motor Carrier Safety Regulations (Hours of Service Regulations)	US Department of Transport	1	3	1	2	2	**9**
Northern Territory Australia Road Transport Fatigue Management Code of Practice	[Unclear which organisation] Northern Territory, Australia	2	2	1	2	2	**9**
Alberta Trucking Industry Safety Association FMP	Alberta Motor Transport Association, Canada	2	2	1	2	2	**9**
US Department of Transport FMP	Federal Highway Administration, US	2	2	1	2	2	**9**

(*continued*)

Table 5.6: (*continued*)

Programme name	**Developing agency**	**Flexible**	**Policy-driven**	**Risk-based**	**Account./audit**	**Comprehensive**	**Overall**
Canadian Pacific FMP	Canadian Pacific Railway	2	2	1	2	2	**9**
Toolbox for Transit Operator Fatigue	Transportation Research Board and Transit Cooperative Research Program, US	2	2	1	1	3	**9**
Air Traffic Controllers FMP	NAV Canada	2	2	1	1	2	**8**
NASA's Fatigue Countermeasures Program	National Aeronautics and Space Administration (NASA), US	3	0	0	0	1	**4**
Shifting to Wellness	Keyano College, Canada	3	0	0	0	1	**4**
Shiftwork like Clockwork	Sudbury and District Health Unit, Canada	3	0	0	0	1	**4**
Ice Navigator Fatigue Module	Transport Canada	3	0	0	0	1	**4**
Averages		**2.52**	**1.95**	**1.19**	**1.62**	**2.10**	**9.38**

3. Risk-based, ‘i.e. does the approach use the level of risk due to fatigue as a means of predicting effectiveness’.
4. Accountability/auditability, ‘i.e. is there a mechanism for monitoring its effectiveness’.
5. Comprehensiveness, ‘i.e. does the approach address multiple (various) organizational factors’.

(Rhodes *et al.* 2005: 6)

Programmes were rated 0–3, with a score of 3 the highest, and 0 the lowest. The highest score that could thus be obtained was 15 (three points for each of the five criteria).

Table 5.6 summarises the fatigue management programmes identified and evaluated. The programmes have been ranked in descending order according to their overall scores. Of the four FRMS trials already discussed, CASA’s FRMS and Queensland Transport’s FMP were considered in the review and have been highlighted in the table.

CASA’s FRMS scored full marks on all five criteria. Its score of 100% does not mean, however, that it is a faultless programme as Rhodes *et al.* (2005) report that all of the programmes had weaknesses.

Many of the programmes assessed gave insufficient consideration to risk management (15 of the 21 programmes scored 0 or 1 out of 3 for this criterion).

The authors conclude with a list of recommendations including:

- a company needs to understand the commitment, costs and benefits of a fatigue management programme;
- all personnel who play a role in fatigue management should be educated on fatigue; and
- a fatigue management programme should consist of (1) policy, (2) education and training, and (3) risk management.

5.8 Summary and discussion – the structure of FRMS and its advantages and disadvantages

This section provides an overview of the structure of FRMS in the trials and summarises the reported advantages and disadvantages of FRMS identified by the evaluations of the trials.

5.8.1 Structure of FRMS in the trials

Table 5.7 summarises the fundamental elements of an FRMS that operators were required to develop in each of the trials. In most of the trials the following five elements were implemented: fatigue management policy, employee reporting system, training and education and auditing.

In contrast, none of the trials seems to have included an explicit requirement to undertake and maintain a risk management process. [14] Rather, certain factors that are likely to cause fatigue were predetermined and operators were required to develop controls. For example, in all the trials, operators were required to consider the impact that rosters have on fatigue and all of the road transport operators were required to consider how the workplace environment can affect fatigue.

While rosters and the workplace environment are undoubtedly important determinants of fatigue, it is essential that operators undertake their own risk management process as part of an FRMS. To effectively manage fatigue risk operators need to understand the particular sources of fatigue that affect them, to assess and prioritise these risks, and to be able to adapt controls to suit their operations, and to do so on ongoing basis. As explained already, fatigue risk management may be specifically undertaken as part of an FRMS or fatigue may be considered in risk management processes conducted as part of a broader Safety Management System (SMS). Either way, where a regulator does not require operators to demonstrate that fatigue risk is being assessed on an ongoing basis, the remaining components of FRMS could become little more than a prescriptive list with which operators must comply and which are unlikely to provide adequate protection against fatigue risk.

The lack of a risk management process seems to be a particularly widespread problem as Rhodes *et al.* (2005) also reported that many of the fatigue management programmes they analysed were not adequately risk-based.

5.8.2 The advantages and disadvantages of FRMS

The reported advantages and disadvantages identified by three of the evaluations that have been conducted of FRMS (the LTSA trial is not included as it was discontinued before sufficient valid data could be collected) are summarised in Tables 5.8 and 5.9, respectively. The results of the evaluations are not directly comparable because the respondents were usually asked open-ended questions and

14 A representative of the New Zealand Transport Agency (formerly known as the LTSA) explained that companies who develop an FRMS are expected to complete a risk and hazard identification and mitigation process, and guidance is provided for them as part of a best practice guide. However, risk management was not included as an explicit standard against which companies are audited as part of the trial.

Table 5.7: Summary of the required components of the evaluated FRMS (where a question mark is shown, it indicates that this element does not seem to have been specifically stated as a requirement)				
Title of programme	**FMP trial**	**CAA NZ scheme**	**LTSA Trial**	**CASA Trial**
Regulator (industry) Component	Queensland Transport (Road Haulage)	CAA NZ (Aviation)	LTSA (Road Haulage)	CASA (Aviation)
Policy	✓	✓	✓	✓
Risk management process	?	?	?	?
Employee safety reporting system	?	✓	?	✓
Incident investigation	✓	✓	?	✓
Training and education	✓	✓	✓	✓
Auditing	✓	✓	✓	✓

due to methodological differences between studies. Thus, the tables highlight common themes and are not intended to be comprehensive.

The three strengths of early FRMS highlighted by all three evaluations are:

- ‘increased safety’;
- ‘an increase in awareness and understanding of fatigue’; and
- ‘greater operational flexibility’.

Safety and awareness are clearly straightforward benefits, but flexibility deserves further attention. As discussed in Section 4.5, when an FRMS has been properly assessed and approved, a by-product can be greater flexibility in that a company may be able to determine their own hours of work (at least to some extent). However, flexibility in HoW needs to be treated with some caution. Some of the managers and staff involved in the CASA trial in Australia believed that flexibility is open to abuse (McCulloch *et al.*, 2003). Pilots were concerned that flexibility in HoW would mean that they would work longer hours and be exposed to greater fatigue under an FRMS. As the primary aim of FRMS is to enhance safety, clearly it is necessary to monitor the added operational flexibility associated with FRMS on an ongoing basis to ensure that it does not have unintended adverse outcomes for safety.

The disadvantages reported for FRMS differed widely between the trials and the only disadvantage cited in two different trials was ‘difficult/complex to manage’. Many of the difficulties faced, such as ‘gaining employee understanding and commitment' and 'industrial disharmony and conflict with enterprise bargaining', are typical of those encountered when attempting any significant operational change. Other disadvantages of FRMS, for example 'over-reliance on fatigue modelling software', are specifically related to the process of fatigue management.

Table 5.8: Reported advantages of FRMS

Title of programme		**FMP trial**	**CAA NZ scheme**	**CASA Trial**
Regulator (transport sector)		**Queensland Transport: Road Haulage**	**CAA NZ: Aviation**	**CASA: Aviation**
Reported advantages				
Safety	Enhanced safety (e.g. reduced risks or less incidents)	✓	✓	✓
Operational	Increased flexibility	✓	✓	✓
	Greater utilisation of employees	✓		
	Enhanced business viability and profitability	✓		
	Lower costs	✓		
Staff	Increase in awareness and understanding of fatigue	✓	✓	✓
	Better able to manage fatigue	✓		
	Reduced fatigue	✓	✓	
	Increased productivity		✓	✓
	Improved performance and judgement		✓	
	Increased mood, morale and motivation		✓	
General	Operating legally	✓		
	Reduced legal exposure	✓		
	Clearer sharing of responsibility for fatigue			✓
	Less complex and easier to use than prescriptive limits			✓
	Scientific basis for fatigue management			✓
	Improved record-keeping	✓		

Table 5.9: Reported disadvantages of FRMS				
Title of programme		**FMP pilot**	**CAA NZ scheme**	**CASA trial**
Regulator (transport sector)		**Queensland Transport: Road Haulage**	**CAA NZ: Aviation**	**CASA: Aviation**
Reported disadvantages				
Safety	Not identifying fatigued employees		✓	
Operational	Loss of flexibility		✓	
	Increased costs	✓		
Staff	Gaining employee understanding and commitment	✓		
	Employee negativity	✓		
	Getting employees to do the training and medicals	✓		
	Industrial disharmony and conflict with enterprise bargaining	✓		
	Decreased productivity			✓
	Employees' desire to work overtime	✓		
	Insufficient staff numbers		✓	
General	Inconsistent enforcement from police/enforcement agencies	✓		
	Increased legal exposure			✓
	Potential for abuse			✓
	Absence of risk assessment			✓
	Difficult/complex to manage		✓	✓
	Increased administrative workload	✓		
	Time-consuming nature of training	✓		
	Time-consuming nature of audit	✓		
	Over-reliance on fatigue modelling software			✓

5.9 Recommendations for regulators regarding the development and implementation of FRMS

The evaluations provide useful information to regulators in terms of implementing FRMS and following this advice could help to avoid repeating some of the problems of implementation that have already been encountered. Table 5.10 summarises recommendations for regulators arising from the various evaluations of FRMS.

The vast majority of recommendations (3–11) advise that, for FRMS to be successful, the regulator should provide detailed but easy-to-understand information and guidance on developing, implementing and maintaining an FRMS and should make the process of developing an FRMS easy to follow for operators. The need for clear guidance was suggested, for example, in the evaluation of the CAA NZ alternative scheme, which found that in the absence of guidance, companies who were supposed to be using FRMS were in fact relying on prescriptive limits instead.

In terms of the content of the guidance, two key topics were highlighted for inclusion: risk management and the use of fatigue models. Risk management is a fundamental component of an FRMS that has often been inadequately performed by operators to date. Subsequently, it is recommended that guidance provided by the regulator should stress the importance of risk management as part of an FRMS and include guidelines on how to assess and prioritise fatigue risks, and develop suitable controls against them where necessary.

The CASA FRMS trial, in particular, identified the problems that can be faced when operators are not introduced to a fatigue model in an informed manner. Accordingly, one of the recommendations to a regulator is to ensure that each operator fully understands what fatigue modelling software can and cannot be used for.

The final three recommendations (12–14) for regulators are amongst the most important and difficult recommendations to follow. These recommendations were not explicitly stated in any of the FRMS evaluations, but can be inferred from one or more of the evaluations. Recommendation 12 advises regulators to audit organisations' FRMS – auditing can help to determine whether operators are actually following through with fatigue management and help to minimise any abuse of flexibility in HoW. However, as none of the evaluations of trials surveyed or interviewed the regulators involved in the FRMS, there is no information on the practicalities of auditing FRMS from the regulators' perspective. There is also no guidance available on how a regulator should audit an FRMS.

Recommendation 13 highlights the important change in attitude and culture that FRMS requires and, as both the CASA and CAA NZ evaluation reports emphasise, the regulator needs to ensure that organisations (including the regulator itself) properly understand FRMS, and the changes it requires.

Table 5.10: Summary of recommendations arising from the various evaluations of FRMS/FMP		
	Recommendations for regulators	**Source(s) of recommendation**
1	Work with industry to develop FRMS	1
2	Consider how an FRMS will influence roadside enforcement	1, 4
3	Provide detailed guidelines on how to develop an FRMS	2, 3
4	Provide an FRMS toolkit including educational and training packages for a company's staff	2, 3
5	Provide comprehensive information for managers on fatigue	2
6	Provide a dedicated internet site or page where information and examples can be accessed easily	2
7	Provide ongoing publications and articles in industry magazines	2
8	Provide detailed information on the commitment, costs and benefits for operators associated with an FRMS	3, 5
9	Provide guidelines on how fatigue modelling should be used	3
10	Provide guidelines on how to assess risk	3
11	Provide advice and processes for developing an FRMS that is as simple and easy to follow as possible	4
12	Audit companies to check that their FRMS are working as they should	6
13	Ensure that all relevant parties (including the regulator) understand FRMS and the change in culture and attitude it requires	6
14	Consider that FRMS may work best as part of an SMS	6

Key
1 = Evaluation of Queensland FMP (Burgess-Limerick and Bowen-Rotsaert, 2002)
2 = Evaluation of CAA NZ alternative compliance scheme (Signal *et al.*, 2006)
3 = Evaluation of CASA trial (McCulloch *et al.*, 2003)
4 = Evaluation of LTSA trial (Denton, 2007)
5 = Transport Canada review of FMP (Rhodes *et al.*, 2005)
6 = Advice not explicitly stated, but which can be inferred from one or more of the evaluations

The final recommendation, consistent with current understanding of FRMS, advises that fatigue management should be considered as part of an organisation's broader SMS. Fatigue then is simply one hazard which the company's SMS should identify and address. This is supported by the CASA trial evaluation which reported that some companies were dissatisfied with the FRMS, as they felt that it failed to consider other risks inherent in the organisation (McCulloch *et al.*, 2003).

5.9.1 Study design

The evaluations of the trials also provide advice for regulators on how to design and conduct a successful FRMS trial. The lessons learnt are as follows:

- It is preferable to collect subjective and objective data. The evaluations conducted thus far mainly collected subjective data to show the advantages or disadvantages of FRMS.
- In the evaluations, participants were asked open-ended questions in order to collect as much information as possible on the strengths and weaknesses of FRMS. The participant's answers could now be compiled into a list and used to add structure to future studies. For example, future participants could be asked to select their answers from the list or comment on each of elements of the list.
- The length of time between the collection of baseline data and the start of the trial should be carefully considered so that changes in industry over time do not unduly influence results.
- A large number of drivers should be recruited to participate in the trial because driver attrition may be high.

In conclusion, the FRMS evaluations that have been conducted have provided valuable information on how FRMS really fares in practice. Overall, the results tend to suggest that FRMS has the potential to enhance safety. However, as only subjective data has been collected to date future research is clearly necessary. Many lessons can also be learnt from the weaknesses, problems of implementation and advice identified through the evaluations.

With the exception of the New Zealand alternative aviation scheme, all of the FRMS trials discussed in Section 5 have now ended and new regulations and guidelines for FRMS have been developed. Section 6 will consider some of the recent regulatory developments in FRMS.

5.10 Summary – the evolution and evaluation of FRMS

- Four FRMS trials have been evaluated to date. Two trials were initiated by road transport authorities: Queensland Transport (Australia) and the Land Transport

Safety Authority (LTSA, New Zealand) and the other two trials were conducted by the aviation regulators of Australia (CASA) and New Zealand (CAA NZ).

- The evaluation of the Queensland FMP trial found that FMP companies were positive overall about the effects of the FMP. For example, they reported that the FMP was effective in reducing driver fatigue and it enhanced flexibility in scheduling.
- The evaluation of the CAA NZ alternative scheme reported that many operators who were supposed to be implementing FRMS were not actually doing so and were still relying on prescriptive limits.
- Although the LTSA trial was discontinued due to changes in regulations, the trial highlighted the problem of driver attrition for data collection, and emphasised that the process of developing an FRMS and guidance on FRMS provided by the regulator needs to be simple and easy to understand for industry.
- The evaluation of the CASA trial found that a majority of participating companies agreed that the FRMS had a positive impact on operations. However, problems in the implementation of FRMS included a lack of risk assessment and the misuse of fatigue modelling software.
- The primary reported advantages of FRMS identified in the trials are that FRMS provides an increased awareness and understanding of fatigue, enhances safety and increases operational flexibility. A notable weakness is that none of the trials seems to have included an explicit requirement for operators to undertake and maintain a risk management process.
- The evaluations of FRMS have provided recommendations for regulators considering introducing FRMS to industry. Most of the advice suggests providing detailed but easy-to-understand information and guidance to operators on developing, implementing and maintaining an FRMS.
- The evaluations primarily collected subjective data, via surveys and interviews with management and employees. It is recommended that future evaluations aim to collect both subjective and objective data.

6 RECENT REGULATORY DEVELOPMENTS IN FATIGUE RISK MANAGEMENT SYSTEMS

6.1 Introduction

Since the evaluation of the FRMS trials, new regulations relating to FRMS in the transport industries have been developed. Most notably, the results of the Queensland Transport trial have contributed to the development of new legislation and guidelines for fatigue management in road transport in Australia. The new regulations enable operators who require greater flexibility in work and rest times to develop systems of fatigue management similar to FRMS.

Section 6 considers recent regulatory developments in FRMS across transport industries in different parts of the world:

- Section 6.2 considers FRMS in Australia;
- Section 6.3 considers FRMS in Europe and in North America.

While the most salient changes in regulation and regulatory guidelines in the last few years are discussed, Section 6 does not necessarily constitute a comprehensive list of recent advances in FRMS regulations worldwide.

6.2 FRMS in Australia – the heavy vehicle driver fatigue reforms

Road transport and aviation regulators in Australia and New Zealand have led the move away from prescriptive HoW limitations towards adopting FRMS across transport industries. The most recent development is the new Heavy Vehicle Driver Fatigue regulations, introduced in September 2008, which replaced the HoW limitations specified by the Road Transport Reform (Driving Hours) Regulations of 1999 (NTC, 2008b). The new regulations, developed by the National Transport Commission (NTC), are an example of outcome-based legislation. Rather than being required to comply with prescriptive rules, companies are required to focus on an outcome (managing fatigue). The regulations are also an attempt to nationalise fatigue management and HoW limitations in a country where these regulations are determined by the government of each individual state and territory (Australian Safety and Compensation Council, 2006).

The new regulations differ from traditional regulatory approaches to driver fatigue in three key ways. First, they emphasise that all operators have a duty to manage their employees' fatigue, consistent with OH&S legislation. Second, chain of responsibility legislation determines that the responsibility to manage fatigue is not solely a responsibility of the driver and the operating company (NTC, 2008c). The legislation identifies a number of parties in the supply chain in road transport who could influence fatigue risk, including the prime contractor, scheduler, consignor, consignee and loading manager, all of which have a legal responsibility for preventing driver fatigue (NTC, 2008c). Finally, the new regulations constitute a multi-model approach in that organisations can follow standard HoW or, if they demonstrate they are managing fatigue in a sophisticated manner, they can work according to more flexible HoW.

The multi-model approach taken by the new regulations consists of three tiers: Standard Hours; Basic Fatigue Management (BFM) and Advanced Fatigue Management (AFM) (NTC, 2008b). The requirements associated with each tier, including the maximum allowed work hours and minimum rest times, are described below and in Table 6.1.

Table 6.1: Maximum work time and minimum rest time under each tier

	Maximum work hours*	Minimum rest times
Standard Hours	12 hrs	7 continuous stationary hrs
Outer limits in BFM	14 hrs	7 continuous stationary hrs
Outer limits in AFM	15 or 16 hrs	6 continuous hrs or 8 hrs in 2 parts

*Work hours include a driver's driving time and time spent by the driver, for example, loading or unloading, cleaning or refuelling, inspecting or repairing a heavy truck or passenger vehicle.

Standard Hours – this option is the 'default'. Operators who do not apply for accreditation for BFM or AFM are subject to these prescribed hours for work and rest (NTC, 2008a). Besides having to comply with these HoW limitations, operators also have a general duty to prevent driver fatigue (NTC, 2008a). The Standard Hours option cuts down the maximum length of a shift from 14 working hours, determined by previous regulation, to 12 working hours (NTC, 2008a).

Basic Fatigue Management (BFM) – if operators would like more flexible hours than those determined by the Standard Hours option, then they can apply for accreditation for BFM. They will need to fulfil six standards of fatigue management 'covering scheduling and rostering, fitness for duty, fatigue knowledge and awareness, responsibilities, internal review, and records and documentation' (NTC, 2008d). The BFM option allows a driver to work for a maximum of 14 hours in a 24-hour period (NTC, 2008d).

Advanced Fatigue Management (AFM) – AFM provides the greatest flexibility in terms of work and rest limitations and the most demanding criteria for managing fatigue. To be accredited for AFM, operators must comply with ten standards of fatigue management and must develop 'a customised and auditable safety management system with controls specific to the fatigue risks of a particular business' (NTC, 2008e: 1). The standards for AFM are very similar to the standards for companies operating under the Queensland FMP trial (see table 5.1). For example, AFM requires operators to 'develop management practices to minimise driver fatigue such as matching drivers to the freight task and good communication practices between drivers and base' (NTC, 2008e: 1). With AFM accreditation drivers can work a maximum of 15 or 16 hours (NTC, 2008a; 2008e).

The NTC stresses that the maximum hours of AFM should not be seen as normal operating hours. The maximum hours are an outer limit and 'only in exceptional circumstances would a driver be allowed to work between the normal operating limit and the outer limit. For example, in the case of an unforeseen and lengthy delay in loading or unloading which greatly extends the driver's work schedule' (NTC, 2008e: 2).

Although the NTC does not use the term FRMS to describe the BFM and AFM programme, the system of fatigue management developed by an operator accredited under AFM would be akin to an FRMS. Like the Queensland FMP trial, however, the AFM approach does not seem to explicitly require a formal and ongoing risk management process. Rather, it specifies areas that are likely sources of risk, for example the roster and workplace conditions, requiring AFM operators to develop controls for mitigating the risks associated with these sources.

6.3 FRMS in Europe and North America

Outside of Australia and New Zealand, FRMS has received the most attention from Europe and North America. The European Aviation Safety Authority (EASA) has published documentation on FRMS and the UK rail regulator has made having a Safety Management System (SMS), including a requirement to manage fatigue, compulsory for train operating companies.

At the start of 2009 EASA released a notice of proposed amendment (NPA) suggesting that all commercial operators will be required to have an FRMS in place by mid-2012 (EASA, 2009). According to the NPA, operators can use an FRMS as a basis for applying for derogation (variation) from existing flight time limitations. To obtain a derogation, an operator will need to present a safety case, successfully demonstrating that an equivalent level of safety can be maintained while working outside of the existing limits.

The NPA consultation period has now closed and EASA's response is due at the end of July 2009. The International Civil Aviation Organisation is also expected to release guidance on FRMS at a later date as an invitation to participate in 'a new Task Force on FRMS with the aim to develop globally accepted standards for the implementation of FRMS' (IATA, 2009).

Well before the release of EASA's NPA, the UK-based short-haul airline easyJet developed an advanced FRMS. The airline commenced development of the FRMS around 2004 in order to support an application to work outside the local flight and duty time limitations (Stewart et al., 2006). The easyJet FRMS has since evolved to include scientific research studies, a crew fatigue reporting system, processes for investigating safety events for fatigue, a fatigue safety action group that meets monthly, fatigue modelling software and the calculation of roster metrics indicative of fatigue (Holmes and Stewart, 2008). The company has reported a range of benefits linked to the FRMS including reduced safety events, attrition and insurance premiums. Other European airlines which have implemented elements of an FRMS include Jetairfly, a Belgian-based charter airline, and German Wings, a short-haul airline operating out of Germany.

Also in Europe, the UK rail regulator has made Safety Management Systems (SMS), with a provision for managing fatigue, a requirement for all operators. Rail companies in the UK, including train operating companies and maintenance companies, are governed by the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS). According to these regulations, each operator needs to develop an SMS to protect against safety risks, including fatigue risk. The ROGS also stipulate that safety critical workers should not carry out safety critical work while they are fatigued. To date, the strategies that rail operators are using to manage fatigue and the extent to which fatigue is being effectively managed has not been assessed.

In North America, FRMS is not embedded in any regulations but this may change soon. Transport Canada, the transport regulator of Canada, has provided guidelines on how to develop a fatigue management programme for marine pilots (Rhodes and Gil, 2002) and they have produced a toolkit for developing an FRMS in the aviation industry (Transport Canada, 2007). Both sets of guidelines are available as public access documents on the Transport Canada website.

In 2008, the National Transportation Safety Board (NTSB) recommended that the US Federal Aviation Authority (FAA) develop guidance for operators to establish scientifically-based FRMS and to design a methodology to establish the effectiveness of these systems (NTSB, 2008).

6.4 Summary – recent regulatory developments in FRMS

- Since the evaluations of FRMS trials, there have been a number of advances in the regulations relating to FRMS in the transport industries.
- The results of the Queensland FMP trial contributed to the development of the NTC's new Heavy Vehicle Driver Fatigue regulations. The regulations are outcome-based and include a multi-model approach to determining hours of work and rest whereby organisations can follow standard working hours or, if

they demonstrate they are managing fatigue in a sophisticated manner, they can work more flexible hours.

- Regulators in Europe have released some published material on FRMS. Notably, EASA has formally suggested that FRMS should be a requirement for all aviation operators in the coming years. The UK rail regulator has made SMS, including a provision for managing fatigue, compulsory for all operators.
- In North America, Transport Canada has made detailed guidelines for the development of FRMS in aviation and the maritime industry available. The NTSB has recommended that the FAA develop guidance for operators to establish scientifically-based FRMS and to design a methodology to establish the effectiveness of these systems.

7 SUMMARY AND NEXT STEPS

7.1 Introduction

This review has explored the literature available on FRMS including academic, regulatory and industry publications. It has established a need for better protection from fatigue risk, defined what constitutes an FRMS, assessed how trials of FRMS have fared in practice, identified the potential advantages and disadvantages of FRMS, and demonstrated what a regulator needs to consider when contemplating the introduction of FRMS to industry.

The literature revealed that relying on HoW limitations to provide protection from the adverse consequences of fatigue risk is increasingly being perceived as an overly simplistic strategy. HoW limitations do not consider the many different factors that contribute to fatigue risk and compliance with rule sets can discourage operators from actively measuring and managing fatigue. As is the case with many other safety risks, a comprehensive risk based and systematic approach to fatigue risk management, namely FRMS, is now advised by the National Transport Commission of Australia and the European Aviation Safety Authority, among others.

An FRMS is a Safety Management System (SMS), or part of an SMS, focused on managing fatigue risk. Within an FRMS, fatigue is managed in a data-driven and flexible manner appropriate to the level of risk exposure and the nature of the operation. An FRMS considers multiple sources of fatigue and provides integrated, multiple defences against fatigue risk. To be effective, an FRMS requires clear lines of accountability, a just culture and the integration of fatigue risk management into a company's everyday business.

In addition to theoretical support for FRMS, the small number of evaluations of FRMS that have been conducted provide encouraging results. The evaluations found that managers and employees were mostly in support of FRMS and felt that it led to improved safety. However, a range of different problems associated with the implementation of FRMS were cited including a lack of availability of clear and user-friendly guidance on FRMS and insufficient attention paid to risk management.

The review found considerable guidance in the literature for a regulator considering introducing FRMS to industry. It is recommended that the regulator:

- works with industry to develop FRMS;
- considers how an FRMS will influence roadside enforcement;
- provides detailed guidelines on how to develop an FRMS that are as simple and user-friendly as possible;
- stresses the importance of risk management as part of an FRMS and SMS;

- audits companies to check that the FRMS is working as it should;
- ensures that all relevant parties (including the regulator) understand FRMS and the change in culture and attitude it requires; and
- considers that FRMS is likely to work best as part of an SMS.

Following this advice could help regulators avoid some of the problems of implementation experienced with the trials of FRMS.

7.2 Next steps: interviews with regulators, operators and other organisations with experience of FRMS

The literature review is only the first part of the Department for Transport review of FRMS. In order to collect further information on FRMS, particularly on how it has fared in practice, the next phase of the project will involve surveys and face-to-face interviews with regulators, operators and other relevant groups with experience of FRMS. Learning from organisations who have already implemented FRMS could help to highlight how best to realise the potential benefits of FRMS and how to avoid problems with its implementation.

As FRMS is a relatively recent approach and there are a small number of organisations with FRMS experience, a world-wide search for people to interview will be necessary and individuals from the road transport, aviation, rail and maritime industries will be approached. Identifying relevant participants will be largely aided by the literature review which has already identified a range of people who it would be valuable to talk to in-depth about FRMS, for example the regulators, operators and researchers involved in the FRMS trials conducted in Australia and New Zealand. Initially, potential interviewees will be sent a survey asking about the fatigue management strategies used in their organisation or the organisations they regulate. The survey responses will be used to identify individuals with experience of FRMS to approach for a more in-depth interview.

The literature review has identified a number of important questions to ask in the survey and in the interviews. The precise content of the questions will be agreed following discussion with the Department for Transport, but below are some suggestions:

- To what extent is your organisation/industry exposed to fatigue risk?
- What methods are used for managing fatigue in your organisation/industry?
- Has an FRMS been implemented in your organisation/industry? Why?
- What does the FRMS consist of?
- What advantages and disadvantages are there to the FRMS?
- What problems in implementation have there been with FRMS?

The results of the literature review and the interviews will inform a comprehensive set of recommendations for the Department for Transport on how to progress with regards to FRMS as a potential strategy for managing the fatigue of commercial drivers in the UK.

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