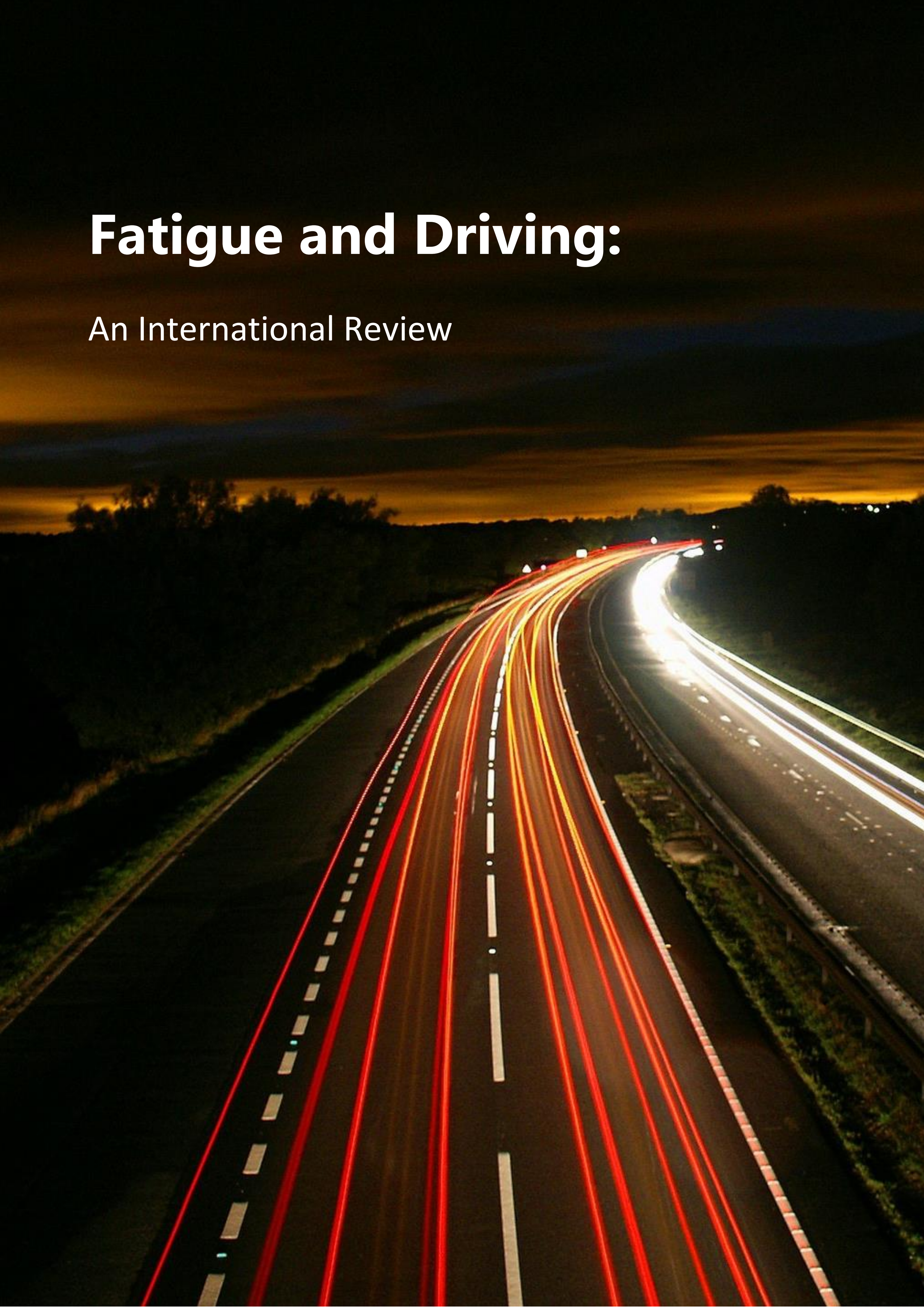
Fatigue and Driving:

An International Review



Client / Project	Australian Automobile Association (AAA) - Fatigued driving Literature Review
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Thanks also to the representatives from stakeholder groups who were generous in sharing resources from their organisations, including Australian and international government department representatives and road safety organisations.

The research undertaken for this review was conducted on Kaurna land. We recognise the Kaurna people are the traditional custodians of the Adelaide Plains, and we pay respects to Elders past, present and emerging.

Conflict of Interest Declaration

Professor Gregory Roach and Professor Drew Dawson were instrumental in developing the FAID biomathematical modelling software identified as one of several bio-mathematical models available for evaluating fatigue-related risk in this report and receive royalties from sales of this product. As such, these authors were not involved in the drafting of the section relating to bio-mathematical modelling, and the authors of that section ensured a variety of models were presented.

Introduction

Fatigue can be defined as a 'suboptimal psychophysiological condition caused by exertion' (Phillips, 2015). In this context, exertion refers to sleep wake behaviour, circadian rhythms, environmental conditions, and individual differences, among other factors (Phillips, 2015). Fatigue is known to result in a range of performance decrements that can negatively impact driving, including slower reaction times, lapses in attention, and altered decision-making (Belenky et al., 2003; Dawson & Reid, 1997). These performance decrements may result in a higher likelihood of lane deviation, difficulty maintaining speed, and a range of other negative driving outcomes (Philip et al., 2005). The most problematic potential outcome of driving fatigued is falling asleep at the wheel. Falling asleep while driving, or having a microsleep (a short period of sleep generally lasting under 15 seconds (Blaivas et al., 2007)), can lead to crashes that result in serious injuries and/or fatalities (due to a lack of pre-crash corrective action).

This review was commissioned by the Australian Automobile Association (AAA). It was undertaken as part of the AAA Road Safety Research Program, to provide an overview of the issues surrounding driver fatigue in Australia and to inform decision making about investments in fatigued driving research. This review examines contemporary scientific literature relating to fatigue and driving and places this literature in the context of current regulatory approaches to managing the risk of fatigued driving. Both Australian regulatory frameworks and international comparators (the United Kingdom, the United States of America, New Zealand, Denmark, Norway, Sweden and Finland) are examined. A systematic literature review was performed using pre-determined search criteria (see methodology section for details) with a focus on the literature published between 2000 and 2020, as requested by AAA. Based on peer review, several additional academic publications were included to present a more complete picture of the current scientific understanding of fatigued driving. Additionally, a grey literature search was performed, and relevant documents included.

The original search criteria for the literature included in this review were based on the following research topics, established via consultation between AAA and the research team:

1. Estimates from the international body of research of the number of fatigue-related crashes in Australia and internationally, including how to identify fatigue crash 'hot spots', and the barriers to identifying fatigue-related crashes;

2. Assessment from the international body of literature about whether, and why, there are at-risk groups for fatigued driving (e.g., young drivers, shift workers);

3. Assessment from the international body of literature about the effectiveness of interventions (including but not limited to technology-based interventions, behavioural-based interventions, and infrastructure-based interventions) to manage fatigued driving;

4. Assessment from the international body of literature about the effectiveness of fatigue management policy and arrangements for different workforces;

5. Assessment from the international body of literature about the effectiveness of fatigued driving advertising campaigns (noting that not all advertising is based on evidence / research);

6. Assessment from the international body of literature about whether drivers recognise they are driving while fatigued, as well as if and why they continue to drive when they know they are fatigued, and what strategies they employ to mitigate fatigue;

7. Identification from the international body of literature of any learnings from fatigue management in the heavy vehicle industry or other industries that could be relevant for light vehicle fleets; and

8. Identification of any gaps in perspectives that are not covered in the international body of literature.

Literature searches were performed to identify literature relevant to research questions one to seven (question eight being addressed during these seven searches). Search criteria and processes can be seen in the methodology section of this report.

The decision was made to synthesise findings from all research questions rather than to answer each question in isolation. As such, this report is presented as a narrative review, addressing the overarching problem of fatigue-related road safety risks. This report also addresses risk mitigation and management strategies (including regulatory and workplace strategies), in addition to behavioural, infrastructure, and advertisement-based interventions. Future priorities in the area of driver fatigue are also addressed from both a research and policy perspective. A comprehensive list of key researchers and research groups is also provided.

Fatigue and driving – defining the problem

In Australia, the existing scientific literature suggests that fatigue contributes to between 2% and 16% of serious road crashes (Filtness et al., 2017b; Mitchell et al., 2015). However, these figures primarily are based on police report data and subjective reports. Given that subjective reports may not accurately reflect the presence or absence of driver fatigue, and co-factors (e.g., speed, alcohol-related impairment) may be given greater consideration by police and/or drivers, it is likely that the actual prevalence of fatigue-related crashes is significantly higher. As such, there appears to be a need for a standardised evidence-based taxonomy to be applied when considering whether crashes are fatigue-related.

A review of the international literature on fatigue-related vehicle crashes suggests considerable variability in the prevalence of both fatigued driving and fatigue-related crash rates, in jurisdictions with comparable road safety records to Australia (e.g., UK and in other countries). These differences are likely due to differences in road safety law, policy, and attitudes in different regions, as well as different approaches to determining whether fatigue was a contributory factor in a crash. A reasonable estimate given the evidence reviewed would be that between 10% and 20% of all major road crashes internationally are likely to have fatigue as a contributing factor.

The existing scientific literature (both Australian and international) highlights several groups that are at higher risk of fatigue-related crashes. These groups include: 1) younger drivers; 2) male drivers; 3) shift workers; 4) drivers with sleep disorders or medical conditions; 5) professional drivers; and 6) new parents. Whilst fatigue-related crashes are not restricted to these groups alone, the higher prevalence of fatigue-related crashes in these groups does suggest that they may be worthwhile targets for specific interventions aimed at reducing the occurrence of fatigued driving.

Given the continued prevalence of fatigue-related crashes, strategies to address the problem need to focus on both driver behaviour and the implementation of appropriate safety systems. While the scientific literature suggests we are more often than not able to identify when we are likely to be fatigued, and therefore at higher risk of crashing, (Williamson et al., 2014), the general consensus is that the decision to continue to drive whilst fatigued is the most appropriate point to target behavioural change interventions. However, it must be noted that while some behavioural interventions may be useful in improving alertness in the short term, the only real way to manage fatigue is sleep. This presents an impractical problem, where behavioural interventions may improve safety to a certain degree, but they are not foolproof strategies for managing fatigued driving.

Managing the risks of fatigue and driving

The various legal, regulatory and policy frameworks that relate to fatigue and driving in Australia can be seen as a suite of interconnected and often complementary elements of our general efforts to manage the risks associated with fatigued driving. One way of viewing the different, yet complementary elements of these approaches is in terms of reactive and pro-active approaches to the issue of fatigued driving.

This review has highlighted that criminal law and civil liability relating to fatigued driving are predominantly *reactive* in their approach. That is to say, these approaches revolve around the outcomes of fatigued driving and serve to primarily provide disincentive and punishment for instances where fatigued driving results in harm or loss. However, beyond general principles of retributive justice, the degree to which reactive approaches change driver behaviour by way of general deterrence appears to be limited.

At the other end of the scale, government and non-government organisation (NGO) policy has adopted a more *proactive* approach, by shaping the nature of, and driving investment in, interventions such as critical infrastructure (roadside rest areas and signage), driver education, and road safety campaigns.

Between criminal law and more general policy guidance, the regulatory frameworks in both Work Health and Safety (WHS) and commercial vehicle (passenger transport and heavy vehicles) contexts are moving towards a more proactive risk-based approach. Drawing on the general principles of hazard identification and risk mitigation, these approaches offer a range of solutions to the problem of fatigued driving from the perspective of work-related driving. Within this context, forms of risk mitigation including journey planning, education and training, fatigue detection technologies, and hours of work limits and minimum rest requirements together offer organisations a range of tools to tackle fatigued driving.

The tools used by organisations to meet their duties to effectively manage fatigue as a workplace hazard appear to have the most potential to be adapted for use across the broader population and outside the context of work-related driving. Whilst there will no doubt be limitations in terms of enforceability and compliance in the general public, the innovative approaches to fatigue risk management afforded through such things as fatigue detection technologies are examples of a more proactive approach to fatigue risk management that in turn have the potential to inform policy for fatigued driving and the general road user.

As there is currently no definitive roadside test for fatigue, regulatory requirements in commercial, professional and road-transport sectors have typically centred on hours of work and rest as a means of reducing the likelihood of fatigued driving. In Australia, fatigue-related legislation is currently focussed on heavy vehicle drivers – despite the effects of fatigue being prevalent in other groups of road users. Heavy vehicle regulation has traditionally focussed on limiting driving hours and prescribing minimum rest requirements as the primary mechanism for the mitigation of fatigue-related risk. This Hours of Service (HoS) approach to risk management has significant limitations, both in terms of reducing actual fatigue-related risk, as well as with compliance and enforcement. More recently in Australia, a risk-based approach has been adopted, where extensions to these HoS limits can be obtained through additional forms of risk mitigation such as driver education, health monitoring, the use of fatigue detection technologies and other risk controls. However, this risk-based approach remains the exception, rather than the norm, with many organisations still choosing to operate within the confines of simple prescriptive limits rather than adopting a risk-based approach (Gärtner et al., 2019). As such, improvements in the management of fatigue-related risk (i.e., the implementation of a risk-based approach) in the professional heavy vehicle driving context are only likely to be achieved through continuing education, enforcement and most importantly, long term cultural change.

Across the range of contexts where driving is undertaken as part of work, one element of a risk-based approach to ensuring health and safety of drivers is becoming widespread. The concept of an individual worker's 'authority to stop' driving if they feel fatigued can be seen as central to many work health and safety approaches to managing the risks of fatigue and driving. Within the context of heavy vehicle regulation in Australia, the law states in that 'a person must not drive a regulated heavy vehicle on a road while he or she is impaired by fatigue' *Heavy Vehicle National Law (South Australia) Act 2013* (SA).[1] This legislative requirement clearly notes that this is relevant even at times when the driver has complied with Hours of Service (HoS) restrictions under the Act and reflects typical organisational practice (Higginson et al., 2019). Effective rostering, journey planning, and more recently the introduction of fatigue detection technologies provide additional layers of risk mitigation.

The scientific literature contains evidence that behavioural countermeasures used by individual drivers can effectively mitigate fatigue-related risk. In particular, the literature highlights caffeine and napping as effective countermeasures. These are already well-known and common features of road safety campaigns. The literature also indicates that some behavioural countermeasures (e.g., winding down a window, using air-conditioning, listening to music), are not as effective as believed by members of the public.

The Safe Systems approach to road safety highlights that safety is a product of more than the driver, the vehicle, and the road conditions in isolation. Rather, the overarching design of a road traffic 'system' in a way that acknowledges the complexity of interactions between the many and varied components of the system is critical in achieving desired safety outcomes. These factors include, for example, the use of evaluation and data regarding safety outcomes, compliance promotion, education, innovation, standards, licensing, and effective management (Australian Government, 2010). Additionally, a key component of this approach is the notion of shared responsibility – between road users and 'system managers' such as governmental and industry organisations (Australian Government, 2010). To this end, infrastructure interventions, from the provision of rest areas through to features such as rumble strips and roadside signage reminding drivers to have a break if tired, play an important part in addressing the risks associated with fatigue and driving and represent an area for future research and development.

As a traditional component of the overarching road safety agenda, advertising and education campaigns will continue to form an important element of managing fatigue and driving. This review has highlighted that further focus on the decision to continue driving whilst fatigued is an important ongoing target for interventions that attempt to achieve positive behavioural change in drivers. Furthermore, the promotion of behavioural strategies such as pre-drive planning (i.e. to ensure that the driver has had sufficient sleep, and will have the opportunity for appropriate breaks during the drive) is likely to have a positive impact on fatigue.

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[1] *Heavy Vehicle National Law (South Australia) Act 2013* (SA) s 228 is used here as an example of the model law adopted across the majority of Australian jurisdictions.

Future priorities

This review has highlighted that fatigued driving remains a very real area for concern with respect to road safety across all road user groups. Estimates of prevalence from the literature suggest that between 2% and 16% of road crashes in Australia are caused by fatigue. Additionally, fatigue has consistently remained as one of the top five road safety priorities in Australia, alongside seatbelt use, speeding, drug and alcohol impairment, and distraction - often referred to as the 'fatal five'.

The review has also highlighted a range of limitations inherent in our current efforts to curb the contribution of fatigue to road crashes in Australia. These limitations include:

- A generally reactive approach to fatigue with respect to criminal and road safety law, whereby driving whilst impaired by fatigue is not construed as an offence in and of itself, until such impairment results in a serious road crash;
- Fatigue is not considered an inappropriate "at-risk" driving behaviour in the same way as speeding or drink-driving by the general population;
- The lack of mechanisms to detect fatigued driving, and therefore limitations with respect to enforceability should driving whilst fatigued become an offence in and of itself, as is the case with speeding and drink-driving;
- A lack of detailed understanding of how to appropriately target behavioural interventions, such as advertising campaigns, to reduce the prevalence of fatigued driving; and
- Limited availability of scientifically validated low-cost fatigue detection technologies for the general road-user population, and appropriate recognition of these devises in vehicle safety standards.

A set of future priorities for addressing the issues associated with fatigued driving are evident.

Fatigue detection technologies

The review has highlighted that as an effective countermeasure against the catastrophic impacts of fatigue and driving, fatigue detection technologies provide an important form of risk mitigation that is currently gaining in momentum in commercial, professional and road-transport sectors. Native fatigue detection technologies are also available in some light fleet offerings in Australia.

The ability to detect when a driver is impaired, either through exhibiting behaviours consistent with a state of drowsiness or through the detection of high-risk driving behaviours such as lane-drifting is an important recent scientific innovation. Fatigue detection systems in general appear to provide valid and reliable tools for fatigue-risk mitigation. Future research with respect to the evaluation of such systems and how they are integrated into an overall systematic approach to managing the risks of fatigue and driving is warranted.

Driver decision-making and stopping driving when fatigued

This review has highlighted that the decision to continue to drive, even when aware of symptoms of fatigue, is the main priority for future research and action in relation to driver behaviour. In the occupational setting, policies and procedures around an 'absolute authority to stop driving', when supported by an appropriate organisational culture, and the necessary road-side infrastructure, provides drivers with support in their decision-making around stopping driving when fatigued.

However, in both the occupational setting and for the general road user, pressures relating to the perceived financial and time costs associated with the decision to cease driving are often perceived to outweigh the perceived risks associated with a fatigue-related crash.

The current science does not provide a sufficiently detailed understanding of driver decision-making in this regard. The science clearly demonstrates that drivers are aware of increasing fatigue levels, and the precursor symptoms of falling asleep. However, we still do not know enough about the underlying decision-making process that leads drivers to continue driving to target appropriate interventions that will lead to behavioural change. Some research exists in the area of speeding and behaviour change suggesting that external motivating factors are perceived as more important than safety (Adams-Guppy & Guppy, 1995), and this may also apply to fatigue. Speeding has been conceptualised under the theory of planned behaviour, which describes behaviours as occurring as a result of intentions (i.e. planned behaviour), which in turn are produced by attitudes, beliefs, norms, and perceived behavioural control (Newnam et al., 2004). This type of behavioural theory may also be applicable to fatigue and driving – though there has been no investigation in this area to date. Similarly, research has been performed into the concept of 'goal seduction' in the areas of emergency management (Bearman & Bremner, 2016) and aviation (Bearman et al., 2009). In this context, goal seduction refers to the performance of behaviours that are unsafe as a result of the desire to complete a goal (Bearman et al., 2009). While goal seduction has not been investigated in the context of driving (either professional or non-professional), future research may produce strategies that encourage drivers to stop driving when fatigued (to stop short of their driving 'goal' if they feel fatigued). As such, the behavioural motivations for driving while fatigued is another clear priority for future research and development.

Preparatory behaviours

A clear future priority for Australian road safety includes a focus on behavioural countermeasures that can be used by drivers to reduce fatigue-related driving risk. There is evidence supporting the use of certain countermeasures, for example napping and caffeine, which have been used consistently in Australian and international road safety campaigns. However, little consideration has been given to preparatory behaviours that could be performed prior to driving to mitigate fatigue-related risk. It is well known that having sufficient sleep prior to driving is a key factor in reducing fatigue-related crash risk. This is a relatively straightforward message that could be included in road safety advertising campaigns in future. Similarly, the promotion of pre-drive planning (particularly long drives) could be effectively communicated to drivers to reduce this risk. For example, drivers could be encouraged to plan long drives at appropriate times of day (e.g. avoiding the early hours of the morning), ensuring that they have had sufficient sleep the night before. Additionally, rest stops and other mitigation strategies could be included in pre-drive planning.

Potential for legal reform – towards enforceability and proactive approaches to fatigue management

This review has highlighted a potential future need for additional legal frameworks with respect to managing the risks of fatigue and driving. Current legal frameworks for managing fatigue in Australia for the general driving population rely almost entirely on the prosecution of drivers for offences relating to dangerous driving - after a crash has occurred. This review has highlighted that the threat of prosecution should a crash occur because of driving whilst fatigued probably provides little disincentive for the general population. The legal and regulatory frameworks adopted in the heavy vehicle industry highlight the role of a greater risk-based approach that takes into consideration factors such as the likelihood of fatigue, through regulating driving hours, and mechanisms to mitigate the risks of fatigue such as enforceable rest periods and the use of innovative solutions such as fatigue detection technologies.

In the USA, 'Maggie's Law' provides one viable alternative approach to managing the risks of fatigue and driving from a legal perspective, by establishing *prima facie* impairment and culpability if a driver has been awake for 24 hours at the time of the crash. Whilst this approach simplifies the decision-making with respect to whether fatigue was a contributory factor in a crash, it probably does not go far enough towards effective legislative disincentive to drive whilst fatigued.

In most jurisdictions worldwide, road safety laws set a prescribed limit of blood alcohol concentration, above which you are 'deemed to be impaired'. That is, driving performance is not used to determine whether an offence has been committed – rather, blood alcohol concentration is used as a proxy. Given appropriate legislative frameworks, driving whilst deemed impaired (from alcohol or drugs) is an offence in and of itself, regardless of whether that driving was in a dangerous manner or whether a crash occurred. It is increasingly possible to translate this approach to the risks associated with fatigue. First, through the measurement of sleep wake behaviours (using technologies such as wearables), and secondly through emergent research establishing valid and reliable assays for roadside fatigue detection through performance test, or other means (Grant et al., 2019).

The science relating to the relationship between sleep, wake, and performance impairment is now at a level of sophistication that we should be able to set threshold levels of an individual's prior sleep wake history that would be consistent with the types of performance impairment we see at prescribed blood alcohol concentrations (Dawson et al., 2020). This is evidenced by the strong relationships seen in the literature between prior sleep wake behaviour and subsequent performance impairment (Belenky et al., 2003; Van Dongen et al., 2003). Within this literature, significant decrements to performance can be seen when there has been fewer than five hours of sleep obtained in the previous 24 hours – performance decrements similar to those seen at a blood alcohol concentration of > 0.05% (Dawson & Reid, 1997). Further, there has been an explosion in the use of wearables that record sleep wake patterns – several which have been validated against 'gold standard' measures of sleep assessment (de Zambotti et al., 2018; Liang & Nishimura, 2017; Svensson et al., 2019). Data from these devices are already discoverable at law, providing a sound basis for exploring the concept of deemed impaired from a fatigue perspective in future law reforms (Dawson et al., 2020).

The concept of 'deemed impaired' is one which has significant merit and potential for future law reform with respect to fatigue and driving (Dawson et al., 2020). The concept of 'deemed impaired' states that a driver is not in a state fit to drive if they have not had sufficient sleep or have been awake for excessive periods. The concept is similar to that of drug and alcohol impairment and the manner in which it is dealt with under road safety law. In most jurisdictions worldwide, road safety law sets a prescribed limit of blood alcohol concentration, above which you are 'deemed impaired'. Given appropriate legislative frameworks, driving whilst deemed impaired is an offence in and of itself, regardless of whether that driving was in a dangerous manner or whether a crash occurred.

The science relating to the relationship between sleep, wake, and performance impairment is now at a level of sophistication that we should be able to set threshold levels of an individual's prior sleep wake history that would be consistent with the types of performance impairment we see at prescribed blood alcohol concentrations. It is critical to note that this is not the same as 'fatigue detection' – but rather a broad level after which most individuals under most circumstances would be impaired due to fatigue, as is the case with determinations of drug and alcohol impairment. Further, the explosion in the use of wearables that record sleep wake patterns, data from which are already discoverable at law, provide a sound basis for exploring the concept of deemed impaired from a fatigue perspective in future law reforms.

Infrastructure interventions and a "fatigue proof" Safe Systems approach.

Infrastructure interventions, as part of a Safe Systems approach, have been shown to be highly effective in mitigating certain aspects of fatigue-related risk for drivers. As such, the promotion and funding of these interventions could be an additional management strategy. For example, increased availability of rest stops in areas where fatigue may be a risk (e.g. rural areas), in addition to the use of controls such as rumble strips and road widening may be effective.

Of particular interest for future developments is the Safe System approach to road safety, as applied to the risks associated with fatigued driving. The Safe System approach, which has been adopted in various jurisdictions worldwide holds that human error is a ubiquitous and fundamental element of the human condition, and that it must be anticipated and accommodated for within the road transport system (Job et al., 2017). To this end, the road transport system must be designed to anticipate and tolerate fatigue drivers. This approach is captured in the concept of Fatigue Proofing a system, where systems are designed to be error tolerant, and the impairment associated with fatigue is prevented from causing harm (Dawson et al., 2012). Currently, road infrastructure interventions, such as rumble strips in place to alert drivers to lane deviations meet the criteria for creating a "fatigue proof" Safe System of road transport. However, a more consolidated and integrated approach is needed to truly create a Safe System for fatigued driving. Given the nature of Australia's road network, road and roadside infrastructure interventions might not be a feasible central component, and in-vehicle technological advancements might be the more appropriate option.

In short, a Safe Systems approach demands some reorientation of our efforts in tacking the problems associated with fatigued driving, away from a focus on prevention, to include a greater emphasis on designing systems that prevent harm from ubiquitous Human Factors issues such as fatigue.

Fatigue Risk Management Systems (FRMS)

In other industries, such as commercial aviation, the creation of Fatigue Risk Management Systems (FRMS) has become the 'gold-standard' for managing occupational risks associated with fatigue. While the complex road transport system presents challenges for adopting an approach typically deployed within the context of a single organisation, the overarching principles of a FRMS could be used as a framework to assist better coordination of efforts in a systematic manner between the various stakeholder groups currently involved in efforts to combat fatigued driving.

A FRMS can be defined as the application of the principles of Safety Management Systems, to the management of fatigue-related risk. To this end, rather than just relying on compliance with prescriptive work and rest rule-sets to manage the safety-related risks of fatigue, a FRMS employs multiple strategies to manage fatigue, such that each strategy forms an additional layer of defence against fatigue.

A FRMS adopts an integrated approach to the management of fatigue through putting in place multiple defences against fatigue-related risk, such as procedures for assessing an individual's fitness for driving or fatigue detection technologies. While a FRMS approach has matured to be recognised as "best-practice" fatigue management in many occupational settings (such as commercial aviation and healthcare), the FRMS approach can also provide guidance as to a better integrated, and more comprehensive, approach to identifying and managing the risks associated with fatigue and driving for the general public. Adopting elements of an FRMS framework might enhance the integration of activities from the wide-range of current stakeholders in road safety, from automobile associations, road safety commissions and other government agencies, not for profit organisations, state and territory police.

In summary, better integration and coordination of efforts from key-stakeholders, and a more systematic approach to delineation of responsibility for specific strategies to combat fatigued driving might be able to be achieved through drawing lessons from the FRMS approach. Similarly, the FRMS approach supports a considered risk-based orientation for these efforts, with an increasing emphasis placed on pro-active strategies that embed a Safe Systems approach to what has been a truly stubborn issue facing road safety in Australia.

Methodology

Topics for review

A review of the international body of literature, for the years 2000–2020, was conducted to address seven topics regarding fatigued driving:

1. Estimates of the number of fatigue-related crashes in Australia and internationally
2. Assessment of whether, and why, there are at-risk groups for fatigued driving
3. Assessment of the effectiveness of interventions to manage fatigued driving
4. Assessment of the effectiveness of fatigue management policy and arrangements for different workforces
5. Assessment of the effectiveness of fatigued driving advertising campaigns
6. Assessment of whether drivers recognise they are fatigued, why they continue to drive when fatigued, what strategies they employ to mitigate fatigue
7. Identification of learnings from fatigue management in the heavy vehicle industry or other industries that could be relevant for light vehicle fleets

Selection of literature for inclusion in review

A five-stage process was conducted to identify and select the relevant peer-reviewed scientific literature and high-quality grey literature for inclusion in the narrative review. The following process was conducted separately for each of the seven research topics:

1. Search Terms – create search terms for five major search engines, i.e., PsycINFO, Medline, IEEE Xplore, Scopus, Web of Science
2. Identification – conduct the five searches, merge the outcomes of the searches, and exclude duplicates
3. Screening – consider studies for inclusion/exclusion based on examination of the title and abstract
4. Eligibility – consider studies for inclusion/exclusion based on examination of the full text manuscript
5. Inclusion – consider the full text of each study and include relevant information in the narrative review

Additional papers were also identified through the peer review process and review of literature cited in articles already retrieved through the search strategy described above.

Grey literature

Grey literature was sourced from online searches (using Google and opengrey.eu), as well as from the Centre for Accident Research & Road Safety – Queensland (CARRS-Q).

Screening process

The screening process for inclusion/exclusion of studies for each research topic is shown by the flow charts below (Figures 1 – 7). Search terms that were used in each search engine for each topic can be found in Appendix A.

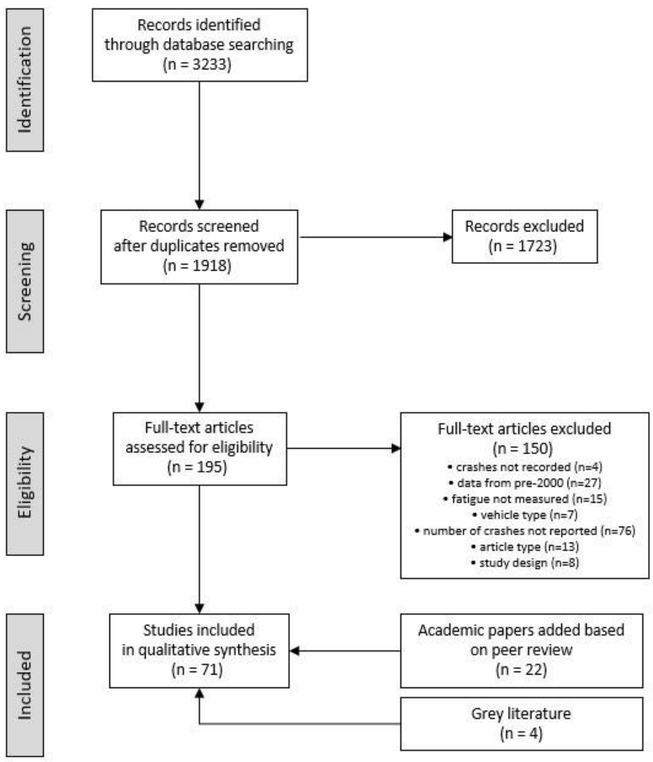

Figure 1. Topic 1 screening flowchart

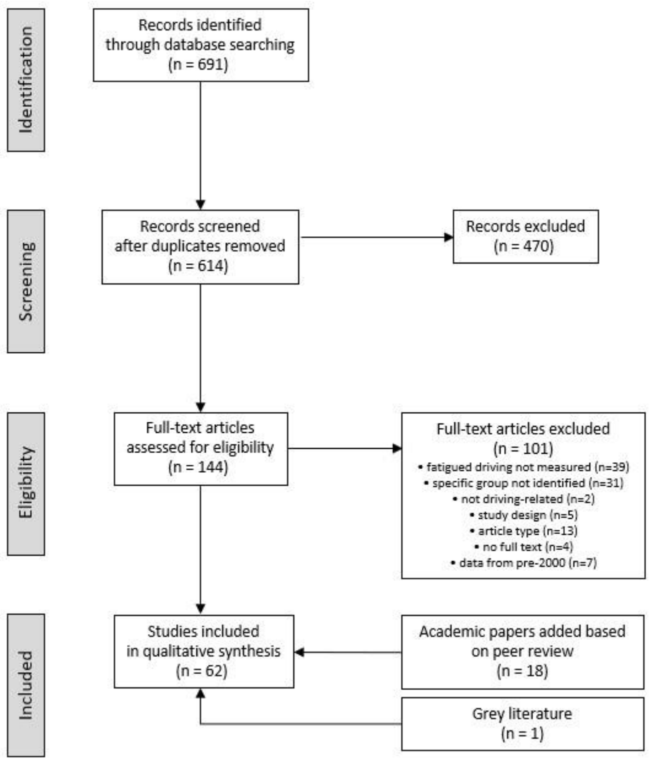

Figure 2. Topic 2 screening flowchart

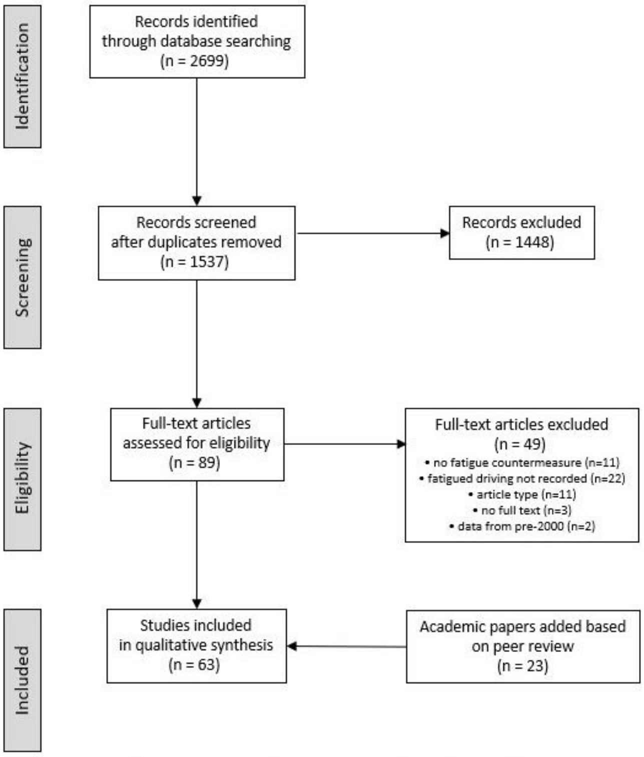

Figure 3. Topic 3 screening flowchart

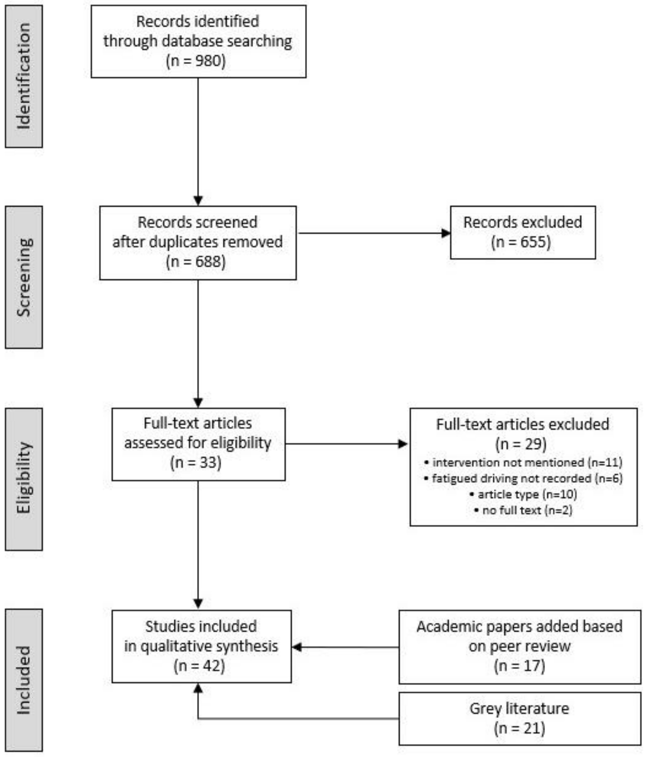

Figure 4. Topic 4 screening flowchart

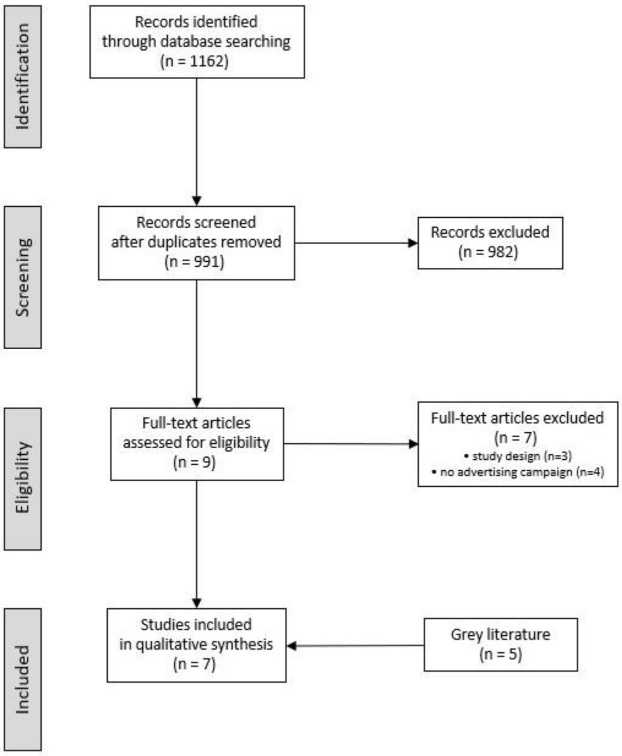

Figure 5. Topic 5 screening flowchart

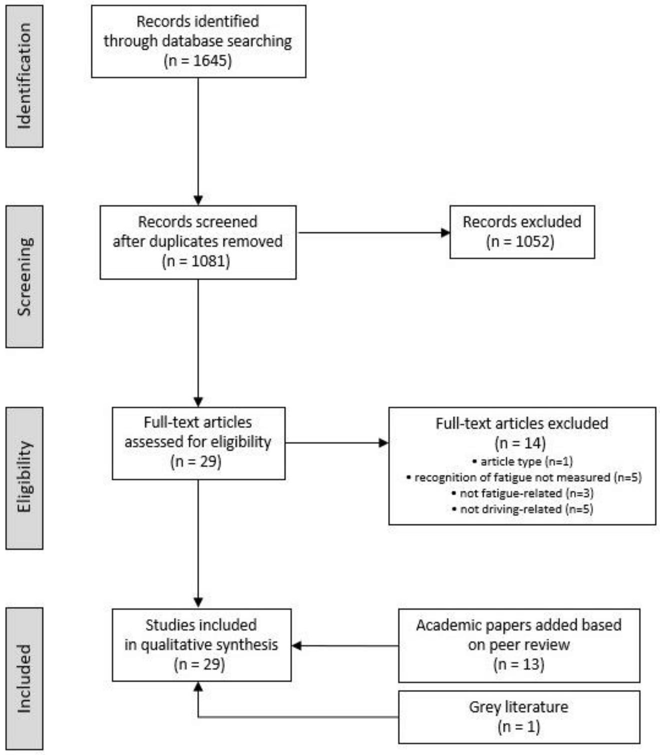

Figure 6. Topic 6 screening flowchart

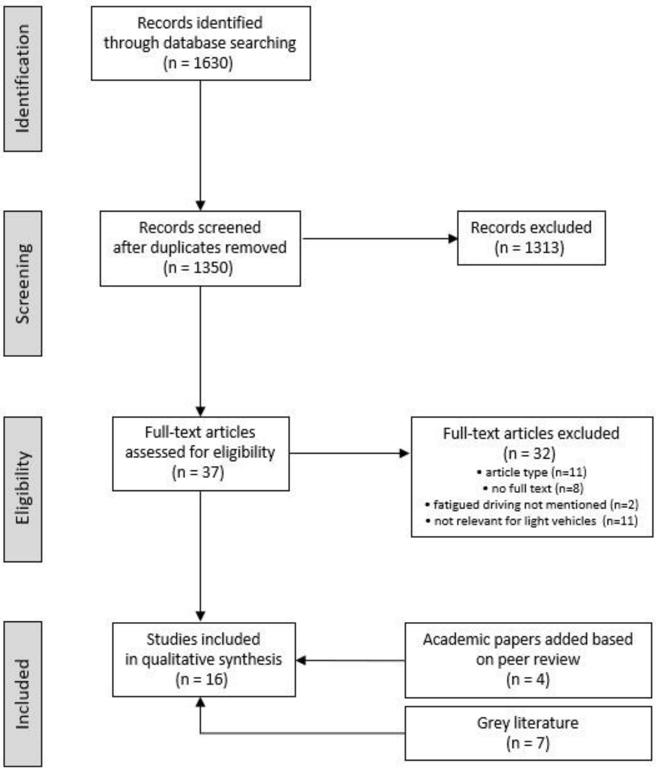

Figure 7. Topic 7 screening flowchart

Stakeholder engagement

As part of the review, stakeholders were contacted by the research team with a particular focus on the sections on legal, regulatory and policy frameworks. Stakeholders were extremely helpful in providing access to resources relating to policy frameworks and individual organisational approaches to fatigue and driving. In addition to this engagement, a range of public domain policy documents were accessed, reviewed, and referred to in the review.

Whilst it is not possible to individually identify all stakeholders who provided information to inform this review due to the large number and considerations of confidentiality, the authors would like to thank the representatives from Commonwealth, state and territory governmental departments, industry associations, and individual organisations who shared with the team resources relating to fatigue and driving.

Presentation of findings

The decision was made to synthesise findings from all research questions rather than to answer each question in isolation. As such, this report is presented as a narrative review, addressing the overarching problem of fatigue-related road safety. Findings have been broken into broad categories that present an integrated response to the original research topics. These broad categories include defining the problems associated with driver fatigue – the causes and consequences of fatigue, driver fatigue prevalence, and locations and groups at greater risk of fatigue-related crashes.

This report also addresses risk mitigation and management strategies (including regulatory and workplace strategies), in addition to behavioural, infrastructure, and advertisement-based interventions. Future priorities in the area of driver fatigue are also addressed from both a research and policy perspective. A comprehensive list of key researchers and research groups is also provided.

Fatigue and Driving – Defining the Problem

What causes fatigue?

The way fatigue is measured and described has been inconsistent in road transport research, with terms such as sleepiness, tiredness, drowsiness, and fatigue used somewhat interchangeably (Phillips, 2015). In 2015, a new definition was developed for use within transport safety research (Phillips, 2015), describing fatigue as a 'whole' concept, encapsulating psychological and physiological outcomes. This definition is as follows:

> "Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional character of the condition depends on the form, dynamics and context of exertion. The context of exertion is described by the **value and meaning of performance to the individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions**. The fatigue condition results in changes in strategies or resource use such that **original levels of mental processing or physical activity are maintained or reduced**" (Phillips, 2015, p. 53).

Fatigue can be caused by a range of factors, including insufficient sleep, excessive time awake, long periods of work, and disruption to circadian rhythms (Brown, 1994; Connor et al., 2002; Tefft, 2018). Humans are a diurnal species, programmed to be awake during the day and asleep during the night (Czeisler & Gooley, 2007). A normal healthy adult requires between seven and nine hours sleep each night, and is usually awake for no more than 16 hours per 24-hour period (Hirshkowitz et al., 2015). When humans exceed these basic parameters of sleep and wake, or alter daily cycles to be awake during the night when designed to be asleep, the likelihood of fatigue-related impairment increases (Banks & Dinges, 2007; Van Dongen & Dinges, 2000).

Fatigue-related impairment (decrements to neurobehavioural functioning) is caused by several key factors, which can be seen in Figure 8. Immediately upon waking, neurobehavioural functioning is negatively impacted by sleep inertia – the feeling of disorientation or grogginess after waking – which soon dissipates. The homeostatic drive for sleep then increases during time awake, resulting in progressive decrements to neurobehavioural performance (Gabehart & Van Dongen, 2017). At the same time, circadian phase impacts performance in a cyclical pattern – i.e. greater performance decrements overnight (Gabehart & Van Dongen, 2017). Internal states and external factors can also impact performance and fatigue (e.g. illness).

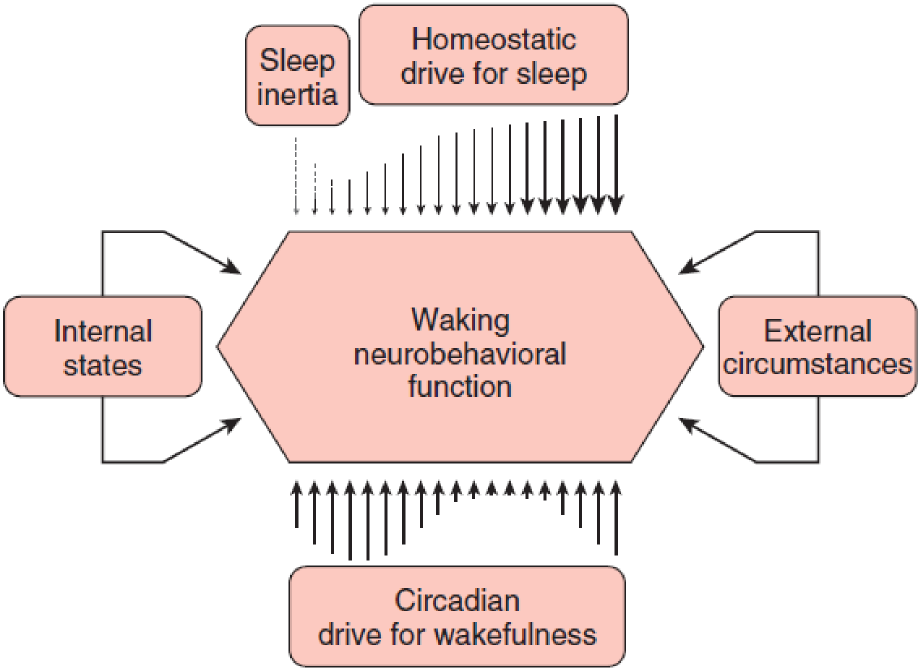

Figure 8. Schematic representation of the conceptual interplay of circadian and homeostatic processes and other factors in the regulation of neurobehavioral functioning (Gabehart & Van Dongen, 2017).

Fatigue and driving impairment

In the context of road safety, fatigue is typically discussed as a cause of impaired performance (Australian Government, 2018). Driving performance impairments such as lane deviations or difficulty maintaining speed are often seen as consequences of fatigue (Du et al., 2015; Philip et al., 2005). These consequences can be caused by the cognitive impairment associated with fatigue, such as slower reaction times, lapses in attention, and altered decision-making (Larue et al., 2011; Matthews & Desmond, 2002; Ting et al., 2008). In the worst case, driving fatigued can result in falling asleep at the wheel – and the associated potential for crashes and/or near misses.

Prevalence of fatigue-related crashes in Australia

Fatigue is often cited as one of the major causes of vehicle crashes in Australia and overseas (Canadian Council of Motor Transport Administrators, 2016; European Road Safety Observatory, 2018;

NSW Government, 2017; Traffic Injury Research Foundation, 2016). Additionally, fatigue has remained as one of the top five road safety priorities in some Australian states and territories alongside seatbelt use, speeding, drug and alcohol impairment, and distraction (often referred to as the 'fatal five') (Government of Western Australia, 2020; Northern Territory Police Fire and Emergency Services, 2020; Queensland Government, 2017; Tasmania Police, 2015; Victoria Police, 2020).

Fatigue is not included in the 'fatal five' in South Australia or the Australian Capital Territory, being replaced by 'dangerous road users' which is inclusive of fatigued drivers (South Australian Police, 2019) and 'intersections', respectively (Australian Federal Police (ACT), 2020). While New South Wales does not use the 'fatal five' terminology, driver fatigue is considered to be a major road safety issue (NSW Government, 2012). Fatigue is a priority on a national level and forms part of the draft *National Road Safety Strategy 2021-2030* (Australian Government, 2020).

Whilst fatigue-related impairment is a serious road safety issue, only a limited number of studies have attempted to define the severity of the issue in terms of the prevalence of fatigue as a contributory factor in crashes. Additionally, there is considerable variation in the overall prevalence rates of fatigue related crashes reported in the Australian studies considered in this review. The highest prevalence rate within the academic literature suggests that fatigue is a contributory factor in 15.6% of crashes (Mitchell et al., 2015). This study focussed specifically on novice drivers in NSW and reviewed 4,113 crashes between 2001 and 2011. Conversely, the lowest prevalence rate seen in published academic literature was observed in a study of 440,855 crashes in Queensland, where fatigue was determined to be a contributory factor in only 1.6% of crashes (Filtness et al., 2017b). It is important to note that this low prevalence rate may be explained in part by the inclusion of all crashes, including motorcycle riders, and low-severity crashes (which are not included in some studies).

The remaining studies highlighted prevalence rates between these two extremes (i.e., 2 – 16%). Of note, a review of 2,530 work-related crashes in NSW that occurred between 2001-2011 found fatigue to be a contributory factor in 13% of crashes, highlighting that fatigue should also be considered as a work health and safety concern (Mitchell et al., 2014). A study examining a sample of 464 crashes in Victoria, Queensland, and New South Wales with known contributing factors, identified that 8% of crashes were attributed to fatigue (Beanland et al., 2013).

The majority of published crash data within the peer reviewed literature in Australia is from the Eastern states – Queensland, New South Wales, and Victoria (Beanland et al., 2013; Filtness et al., 2017b; Mitchell et al., 2015), and is primarily based on post-crash driver interviews and crash details (e.g., engineering reports on crashed vehicles, police reports). Given differences between the states and territories such as terrain or traffic density, studies investigating the prevalence of fatigue-related crashes in populations from South Australia, Tasmania, Western Australia, and the Australian Capital Territory and Northern Territory are also needed. In addition, direct comparisons between states and territories in terms of fatigue-related crash prevalence proportions would identify contributory factors (e.g., road conditions, local legislation / regulations, demographics) that may require targeted management approaches at the state/territory level.

A key similarity between many Australian studies is that the reported prevalence of fatigue as a contributory factor relied primarily on police crash reports or the application of proxy measures to crash data (Armstrong et al., 2013; Filtness et al., 2017a). Proxy measures are post hoc analyses based on state determined criteria for fatigue-related crashes (e.g., speed, solo vehicle accident, etc.), as opposed to the assessment of an on-scene police officer. A recent review highlighted a range of deficiencies in the ways in which Australian police make a determination of fatigue as a contributory factor in crashes (Dawson et al., 2018). Standard criteria for a crash having been fatigue-related take an opportunistic retrospective approach. A rigid set of inclusion and/or exclusion criteria may result in crashes being classified incorrectly or inadequately. For example, the Australian Transport Safety Bureau criteria indicate that a crash will not have fatigue as a contributory factor when speeds are below 80km/h, there is a pedestrian involved, the driver is under the influence of alcohol or other drugs, or the driver does not hold a current license (Dobbie, 2002). These criteria therefore would fail to identify fatigue as a factor in a crash where any of these circumstances were present (Dawson et al., 2018). Therefore, it is likely that the current literature underestimates the true number of crashes that have fatigue as a contributing factor, as it is not currently possible to 'test' for fatigue after a crash.

Australian-based studies also typically focus on crashes that required hospitalisation, indicative of a serious injury to the driver or passenger. As fatigue is often a contributory factor to near-misses and crashes that do not result in serious injury (Williamson & Boufous, 2007), this criterion may also contribute to under-estimation of prevalence rates. It is important to note that while fatigue-related crashes may result in serious injury or fatalities in cases where the driver has fallen asleep and has not engaged in any corrective actions prior to impact, we must also consider crashes that result from poor decision-making, slowed reaction times, distraction, and other performance decrements. These incidents, while less serious, are less likely to be included in crash statistics. Self-report data from Australian road users, which indicated that just 45% of fatigue/sleep related crashes involved the police (Armstrong et al., 2013) suggest a much higher prevalence rate. In addition, near misses, where a driver has woken at a critical moment prior to a potential crash, are also not captured in studies assessing fatigue-related crash risk.

Studies based on data obtained from police reports and/or relevant proxy measures, are complemented by Australian research using driver self-report of crash causes, though typically with specific populations rather than with representative samples of all Australian drivers. For example, one interview study focused on heavy vehicle drivers found that 39 – 40% of all drivers in the study (both those who had crashed and those two had not) reported having trouble staying awake while driving over the previous month – though crash prevalence was not included in this study (Stevenson et al., 2013). Another study compared self-reported contributory factors of crashes and near misses with proxy definitions of fatigue-related crashes in a group of over 1,600 Australian drivers (Armstrong et al., 2013). In addition to indicating that proxy definitions of fatigue-related crashes may not capture all instances of crashes or near misses that were fatigue related, this study suggested that 66% of participants had driven while fatigued or sleepy, 19% reported fatigue-related near misses, and 2.4% of participants reported being involved in a fatigue-related road traffic incident (Armstrong et al., 2013). Similarly, in a sleep clinic population, 26% of participants reported having had a near miss because of fatigue, while 11% of crashes were attributed to fatigue and/or falling asleep behind the wheel (Ward et al., 2013). However, it must be noted that a sleep clinic population is more likely than the general population to have a sleep disorder. In a population of young drivers, having shorter sleep periods the night before was associated with an increased crash risk, though the proportion of crashes directly attributed to fatigue was not reported (Martiniuk et al., 2013). While these self-report-based studies can provide insight into the proportion of certain population groups who may be at greater risk of fatigue-related near misses or crashes (e.g., heavy vehicle drivers, sleep clinic populations), findings are not necessarily generalisable to the Australian population.

Rates of fatigue-related crashes are also reported within the grey literature, though the data on which these figures are based are often unclear. For example, the now expired *National Road Safety* Strategy 2011 – 2020 (Australian Government, 2010) reported that 20- 30% of all total crashes, and 8% of all serious injuries had fatigue as a 'main behavioural factor' – though no references are provided. Similarly, a 2015 report detailing crash statistics from Western Australia indicated that 11% of fatalities were due to fatigue-related crashes (down from 16% in 2014), though no detail is provided as to the cause determination strategy used other than being obtained from the Road Crash Casualty Database (Government of Western Australia Road Safety Commission, 2016). In an overview of fatigue-related crashes in New South Wales between 2008 – 2016, it was found that in 2016, 21% of fatalities were associated with fatigue, as compared with between 14 – 20% each year from 2008 – 2015 (NSW Government, 2017). These figures were determined based on police reports and crash characteristics.

It is important to note that many (though not all) driver fatigue studies, both in Australia and worldwide, rely on the classification of fatigue as a contributing cause of crashes through reports from people other than the driver. This includes reports by police officers attending crash scenes and reports from crash investigators at the scene. Unlike detecting the contribution of drugs or alcohol, it is difficult to accurately detect fatigue-related impairment. Fatigue is often determined to be the contributing cause due to indicators such as crossing the centre line, running off of the edge of the road, and the frequency of lane excursions (Armstrong et al., 2013). There are currently no objective and reliable tests to measure fatigue following a crash (Dawson et al., 2018). In laboratory studies, fatigued driving is often signalled by microsleeps and increased inattention and distractibility (Golz et al., 2011; Moller et al., 2003). However, these events are hard to ascertain post-crash, particularly by a police officer or attending crash investigator. Further, in some jurisdictions outside of Australia, police officers report a lack of training on how to identify driver fatigue (Radun et al., 2013). In Australia, no information is currently available on whether police officers are provided with effective training on the identification of driver fatigue. The internationally identified lack of appropriate training likely reflects a general uncertainty in how police should identify whether driver fatigue contributed to a crash. Though there is a lack of available evidence in the Australian context, training on determining whether fatigue is a contributory factor to a crash is critical for establishing accurate prevalence rates.

In summary, the existing scientific literature suggests that in Australia fatigue contributes to between 2% and 16% of serious road crashes. However, given the reliance on post-crash police reports to provide data, and the potential impact of subjective reporting and/or the attribution of crashes to other co-factors, the actual prevalence of fatigue-related crashes is likely to be significantly higher. In addition, the severity of fatigue-related crashes may be greater than other vehicle crashes, due to higher impact speeds (i.e., no last-minute avoidance behaviours performed by drivers).

Prevalence of fatigue-related crashes internationally

The scientific literature highlights significant differences in prevalence rates of fatigue-related crashes in different countries and jurisdictions. The main countries and regions used for comparison in this review are countries in Europe, the USA, the UK, Canada, and New Zealand – though some information from Asian, African, and Middle Eastern counties is also presented. A study measuring the prevalence rates of fatigued driving in nineteen pan-European countries found that 17% of 12,434 drivers had fallen asleep at the wheel, 7% of these drivers had a fatigue-related crash, and 3.6% had been involved in a fatigue related crash leading to a fatality (Gonçalves et al., 2015). A study identified that in the USA, 6% of 1,020 crashes were caused by fatigue (Adanu et al., 2018), while 34% of 5,470 drivers reported drifting out of their lanes while sleeping (resulting in a high risk of crashing) (Cicchino & Zuby, 2017). A much higher proportion of crashes having fatigue as a contributing factor was seen in the 100-car study conducted in the USA (Klauer et al., 2005). This naturalistic driving study found that 12% of crashes were fatigue-related. Additionally, in 2014, the AAA Foundation for Road Safety in the USA reported that fatigue was involved in 21% of all fatal crashes, and 13% of all serious injuries occurring from crashes (Tefft, 2014). This suggests that a higher proportion of severe and/or fatal crashes (as opposed to all crashes) may be solely or partially caused by fatigue. In Canada, the rate of fatigue as a contributory factor is estimated to be between 4 – 8% of all total fatalities – though this figure is based on police reported collision data and coronial reports (Traffic Injury Research Foundation, 2016). This is a similar rate seen within a study based on proxy identification of fatigue as a cause of a crash performed in France (Philip et al., 2001). Phillip and colleagues (2001) reported a fatigue-related crash rate of 10% using a proxy measure (i.e., a taxonomy used to classify whether fatigue was present as a cause of a vehicle crash) which includes the following criteria:

> *(a) breathalyser/blood alcohol levels below the legal driving limit;*
> *(b) the vehicle either ran off the road or ran into the back of another vehicle;*
> *(c) no signs of the brakes being applied beforehand (for example, no skid marks);*
> *(d) no mechanical defect in the vehicle (or burst tyre);*
> *(e) good weather conditions and clear visibility;*
> *(f) elimination of "speeding" and "driving too close to the vehicle in front" as causes;*
> *(g) the police officer(s) at the scene suspected sleepiness as the prime cause;*
> *(h) for several seconds immediately before the accident the driver could have seen clearly the point of run off or the vehicle hit. The driver may or may not have admitted to having fallen asleep.*
> *Criteria (a) to (h) had to apply for the data to be acceptable as a sleep related vehicle accident. Criterion (h) also implies prolonged inattention rather than momentary distraction, but this cannot be assumed.*
> (Horne & Reyner, 1995, p. 310)

First described by Horne and Reyner (1995), the taxonomy was based on police databases and interviews and the original study reported that 16% of crashes on major roads, and 20% of crashes on motorways in England were fatigue or sleep-related (Horne & Reyner, 1995).

Given the large datasets used in these studies, the range of between 10% and 20% of road traffic accidents being fatigue-related are likely to be generalisable to similar jurisdictions.
However, the strength of this finding is linked to the validity of the proxy measure and, as mentioned above, there are inherent limitations of this type of data analysis, (e.g., this taxonomy assumes that an individual cannot be both speeding and fatigued, or cannot be fatigued under good weather conditions with good visibility) and findings should be interpreted in that context (Dawson et al., 2018).

In New Zealand a self-report study compared just under 600 drivers involved in crashes to a similar group of drivers who had not been involved in a crash (Connor et al., 2002). Drivers who had high sleepiness ratings (measured via the Stanford Sleepiness Scale) were eleven times more likely to have been involved in a crash, though population level prevalence rates of fatigued driving or fatigue-related crashes were not provided. Similar findings were reported in a French study on predictive factors of crashes based on interviews with drivers who had been hospitalised post-crash, with matched controls (Philip et al., 2014). Findings indicated that 10.3% of all crashes had sleepiness as a contributing factor, with 6.2% of participants reporting that they were asleep immediately before the crash. A recent worldwide survey also found that a high proportion of drivers reported driving 'while having trouble keeping their eyes open' at least once in the previous 30 days (Australia - 17%; Canada – 22%; France – 18.5%; Ireland – 24% Japan – 33%; Netherlands – 22%; UK– 15.3%; USA – 22%) (SWOV Institute for Road Safety Research, 2019).

The experience of drowsy driving was also reported by participants from Asia, with 52.3% of commercial drivers in South Korea experiencing drowsy driving, and a further 9.6% experiencing fatigue-related crashes (Kim et al., 2018). For studies in African populations, the prevalence of fatigue-related crashes ranges from 4% (when all types/severity of vehicle crashes were included in a sample, n = 571) (Adeoye et al., 2014) to 48% (of vehicle crashes that resulted in a fatality, n = 176) (Abegaz et al., 2014). The difference in prevalence rates between these two studies suggests that while fatigue may result in a comparatively low proportion of total crashes, fatal crashes (or crashes resulting in severe injury) are much more likely to have fatigue as a contributory factor. Lastly, for countries in the Middle East, the prevalence of fatigue-related crashes ranged from 11.6% of 773 crashes in Iran (BaHammam et al., 2014) to 0.29% of 5,775,078 injuries sustained in urban crashes in Iran between 2004 and 2010 (Bakhtiyari et al., 2016).

The literature indicates that the prevalence of fatigue-related crashes internationally varies significantly. While this may reflect several factors, including road type, traffic density, and population demographics, one main factor relates to the way in which crashes were determined to be fatigue-related. A significant number of studies on fatigue-related crash prevalence internationally rely on self-report to determine crash cause, which may also impact reported prevalence rates. For example, in the study by Gonçalves et al. (2015), drivers from 19 European countries completed questionnaires about the frequency of falling asleep at the wheel which resulted in a crash. Self-report is likely to identify more crashes than those captured through police-report, but it does rely on participants being aware of their fatigue levels at the time of the crash, and honestly reporting incidents. Further, in the study by Herman et al. (2014), drivers in Fiji were interviewed in the hospital immediately after the crash and asked about the circumstances relating to the crash. This method allowed for a description of the driver's state at the time of the crash from the driver's perspective. Interviews conducted immediately following a crash may provide for more accurate detection of prevalence rates, but it requires significant resources and is still unlikely to capture all fatigue-related crashes.

Additional methods of fatigue detection amongst the international studies include telephone interviews about past experiences of fatigued driving (Sagaspe et al., 2010), and questionnaires completed by crash experts on the frequency of fatigue contributing to crashes they have attended (Bakhtiyari et al., 2016). Some international studies used samples of commercial drivers (Kim & Oh, 2019), which may result in higher prevalence estimates of fatigue-related crashes due to an increased likelihood of these populations performing shift work and/or having demographic factors that are associated with increased risk (Crummy et al., 2008). International studies have also included a broad range of driver types. For example, one Italian study indicated that in a population of high school students, 24% reported having had a crash, with 15% of crashes being attributed to sleepiness (Pizza et al., 2010). Another example is a sample of truck drivers from Portugal, who reported that 42.5% of near misses, and 16.3% of crashes were 'sleep related' (Catarino et al., 2014). Additionally, international research has investigated a range of crash types - for example, the prevalence of fatigue in crashes that occurred on the freeway (22.5%) (Kim & Oh, 2019), and run off road crashes that were caused by overcorrection (9.6%) (Spainhour & Mishra, 2008). Future studies into fatigue-related crashes in Australia would benefit from a wider representation of drivers, including commercial drivers, shift workers, and regular commuters, in addition to different crash-types, to allow for comparison to the international studies and a better understanding of the problem in the Australian context.

While prevalence rates were also identified from international studies, including China, Ethiopia, Fiji, France, India, Iran, Italy, Japan, Madrid, Nigeria, Poland, Portugal, Romania, South Korea, Switzerland, and the UAE and USA, overall, most of the international studies were conducted in European countries, closely followed by China and the USA. While there are numerous studies on crash rates in non-Westernised countries (Bener & Alwash, 2002; Olukoga, 2004; Tulu et al., 2013), studies on fatigue-related crashes are lacking and warrant further research.

In summary, the review of the international literature on the prevalence of fatigue-related crashes highlights considerable variability in prevalence rates, which likely reflects not only jurisdictional differences but also the difficulty in determining whether fatigue was a contributory factor in a crash. A reasonable estimate given the evidence reviewed is that between approximately 10% and 20% of road crashes internationally are likely to have fatigue as a contributing factor.

On road hot spots – where is fatigue most likely?

Much of the literature and available statistics indicate that rural (or otherwise non-urban) roads are associated with higher rates of fatigue-related crashes (Australian Transport Council, 2011; Queensland Government, 2019; SWOV Institute for Road Safety Research, 2019). Statistics provided by the Australian Transport Council (2011) indicate that head on crashes, particularly those on high speed rural roads, are likely to be associated with fatigue, often due to lane deviation. This is supported by evidence from Queensland, noting that fatigue is often a contributory factor for crashes on regional roads (Queensland Government, 2019). Recent research conducted in 32 countries including Australia (using a self-report methodology) also indicates that fatigued driving is far more prevalent in semi-urban and rural areas than in urban areas (SWOV Institute for Road Safety Research, 2019). This aligns with Australian road classification statistics (from New South Wales) based on fatigue related fatal crashes, which indicate that state highways are the most common location of these events (28% in 2016), followed by other classified (21%) and unclassified (22%) roads (i.e. local roads) (NSW Government, 2017). In New South Wales, few fatigue-related fatalities were reported on freeways or motorways. It must be noted, however, that these figures do not reflect all fatigue-related crashes, but instead just those that resulted in a fatality. As such, it is likely that speed and other road conditions on certain roads (e.g., state highways) may have also impacted these figures as a fatigue-related crash may be more likely to be fatal if the driver is travelling at high speed on a two-lane highway. Trends in serious injury fatigue-related crashes differed, with higher crash rates seen in unclassified and classified roads, as opposed to state highways or freeways. A NSW crash statistics report also indicated that higher rates of fatigue-related fatal and serious injury crashes occurred on Friday, Saturday, and Sundays, and during the night (00:00 – 06:00 h), as compared with other time periods (NSW Government, 2017). Furthermore, higher rates of fatigue-related crashes were seen in the late afternoon, which aligns with the secondary circadian low point (i.e., the post-lunch dip in alertness caused by our 'body clock') (NSW Government, 2017).

The findings presented within the Australian context above are largely provided by government and road safety bodies, and are primarily based on data acquired from police accident reports (Armstrong et al., 2008). While fatigue-related crashes occur in any road conditions, they are more likely when driving at speed in non-urban areas (Palamara et al., 2007). This is also reflected in other jurisdictions, though limited academic research is available on the subject. For example, similar findings are present in New Zealand (Smith et al., 2006). In the UK, higher levels of fatigue-related crashes were seen based on the type of vehicle and driving that was performed (i.e., drivers of large goods vehicles were most likely to experience a fatigue-related crash) (Clarke et al., 2009). This study also noted that these accidents were also most likely to occur on motorways – where surroundings were monotonous, and speed limits were high (Clarke et al., 2009). In a study conducted in Hawaii – a location with limited opportunities for long distance driving (due to the size of the islands) – there was still a notable difference in the likelihood of fatigue-related crashes occurring on freeways or motorways (Kim & Yamashita, 2001).

Driver groups at higher risk of fatigue-related crashes

Several important streams of research have highlighted different driver groups that are at higher risk of fatigue-related crashes.

Younger Drivers: A driver's age has been identified in several key studies as a factor contributing to fatigued driving (Hutchens et al., 2008; Obst et al., 2011; Pack et al., 1995). Overall, these studies suggest that younger drivers are at greater risk of fatigued driving compared with older drivers. In an early study conducted in the USA, 55% of fatigue-related motor vehicle crashes occurred in drivers aged 18-24 years as compared with drivers 25 years and older (Pack et al., 1995). Importantly, these young drivers were 14.2 times more likely to crash during the night-time hours or during early morning driving. This differs from older drivers (aged over 45 years), who were less likely to experience fatigue-related crashes overnight, but were at higher risk during the afternoon (Pack et al., 1995). In the Australian context and in a Queensland study, drivers aged 25-34 years were more likely to report driving when sleepy, compared to drivers aged 55-64 years and 65 years and over (Obst et al., 2011). Also, in an Australian population, 84.6% of a sample of 1,076 drivers aged 18-20 years reported driving while tired, though no comparisons to older age groups were made (Scott-Parker et al., 2014). Further evidence for a greater driving risk in younger drivers was found in international studies, with

53.8% of 506 14-22 year old drivers in the USA reporting driving while tired (Hutchens et al., 2008), and 33% of 695 drivers aged 18-22 years old in Italy reporting sleepy driving within the past six months (Lucidi et al., 2006). However, it must be noted that neither of these studies included comparisons with older age groups. Despite this, findings suggest that there is a significant risk for fatigued driving amongst drivers below 25 years of age. However, many of these studies do not include groups of older drivers, and thus do not allow for a direct comparison between age groups.

Simulator studies also suggest that there is a greater degree of vulnerability to driver fatigue for younger drivers (Campagne et al., 2004; Filtness et al., 2012; Lowden et al., 2009). For example, one simulator study compared driving outcomes (e.g. lane deviations) in groups of younger (average age 23 years) and older men, finding that under sleep restriction conditions (five hour sleep opportunity), younger men performed significantly worse than their older counterparts (Filtness et al., 2012). These findings are further supported by simulator studies which have found that the negative influence of low vigilance levels on driving performance decrease as a function of older age during a driving task after sleep restriction (Campagne et al., 2004), in addition to greater self-reported sleepiness from younger drivers overnight (Lowden et al., 2009). It must be noted, however, that younger drivers, who are overrepresented in crash statistics, are also typically new to driving (Filtness et al., 2017b). As such, it is unclear whether it is age or driving experience – or a combination of both – that results in an increased likelihood of being in a fatigue-related crash.

University students have been identified as an at-risk group for fatigued driving (C. J. Lee et al., 2016). In this study, 580 American university students completed a driving behaviours survey, with 72% of students reporting a drowsy driving experience, and 41% reporting an incident of falling asleep while driving. It is likely that university students are a high-risk population in many countries, as they generally fit into the 18-25 age group. The fatigued driving risk of university students warrants further research, as there may be other contributory factors that impact risk in this population (e.g., lifestyle factors and/or driving locations).

There is some evidence to suggest that older drivers (60+ years of age) may be more negatively impacted by circadian effects during the day (NSW Government, 2017). Fatigue-related crash statistics published by the NSW government indicate that this age group was significantly more likely than other age groups (<30 and 30 – 59 years) to be involved in a fatigue-related serious injury crash between midday and 16:00 hrs – a typical circadian low point for a normally entrained individual[2] ("the post lunch dip") (NSW Government, 2017).

Male Drivers: Males may be at greater risk of fatigued driving compared to females (Filtness et al., 2012; Pack et al., 1995; Radun et al., 2015). The majority of reviewed studies used data from self-report methods, such as questionnaires and interviews. Pack et al. (1995) found that 74.5% of all crashes in North Carolina where the driver fell asleep at the wheel occurred with a male driver. In a sample of European drivers, researchers identified that males were also significantly more likely to report falling asleep at the wheel and to report difficulty staying awake than women (Radun et al., 2015). This suggests that even if males do not crash the vehicle, they may be more likely to drive while experiencing fatigue-related impairment. This is also reflected by a recent worldwide survey, which found that in Europe, North America, and Africa, driving while fatigued was reported by considerably more males than females (SWOV Institute for Road Safety Research, 2019).This report indicated women were 47% less likely than men to drive while fatigued. Young males may also be disproportionately negatively impacted by sleep loss, compared with older males, as suggested by a study into driving outcomes following sleep restriction (Filtness et al., 2012).

In Australia, a study by Boufous and Williamson (2006) found that of 13,124 drivers who were injured or died because of a work-related crash in the period 1998-2002, 7.6% of males were fatigued at the time of the crash compared to 4.2% of females. Though this was a direct comparison that did not include confounding factors in the analyses, the authors note that higher levels of work-related fatalities in men are associated with an increased likelihood of working in transportation industries. It is possible that the increased likelihood of driving while impaired relates to work scheduling and/or the type of industry because men are more likely to perform shift work (Australian Bureau of Statistics, 2010), though more research is needed to investigate this potentially confounding variable. Additionally, there is evidence to suggest that men are more likely to engage in risk taking behaviour, which may also partially explain the differences in the likelihood of driving while fatigued (Turner & McClure, 2003).

Although males were identified as more at-risk for driving while fatigued, female participants in studies investigating gendered differences in fatigued driving still reported fatigue related driving

[2] 'Normal entrainment' refers to having a circadian rhythm ('body clock') entrained to sleep at night and be awake during the day. This is in opposition to someone who is, for example, performing shift work and is required to be awake overnight.

errors (Filtness et al., 2012; Obst et al., 2011; Pack et al., 1995; Radun et al., 2015). For example, in the Australian study by Obst et al. (2011), while male drivers were considered more at-risk for fatigued driving, with 39% of male drivers reporting a near-miss and 25% of females reported sleepiness related near-misses. Thus, while women are at risk of fatigued driving, the risk is lower when compared to men.

Shiftworkers: Several studies identified shiftworkers as at-risk for fatigued driving (Anderson et al., 2018; Barger et al., 2005; Dorrian et al., 2008). Studies used surveys, driving logs, and police reports, and populations including resident physicians, long-haul drivers, nurses and shiftworkers in multiple shift-types. For nurses, driving home from a nightshift was associated with a high risk of fatigue, with 50% of extreme drowsiness and near misses occurring between 07:00 hrs and 09:00 hrs (Dorrian et al., 2008). Additionally, driving home from work after an extended shift was associated with a greater prevalence of fatigue related adverse driving events compared to driving to work, in a sample of Australian medical trainees (Anderson et al., 2018). Further, working multiple extended shifts during a week further increased the risk of falling asleep while driving or when stopped at traffic (Barger et al., 2005).

Working greater than 40 hours per week also increases odds for drowsy driving (Swanson et al., 2012). Crummy et al. (2008) found, based on a study of 112 injured drivers in Australia, that shift work was the greatest sleep-related factor to contribute to motor vehicle crashes. This is also reflected in a real world study of shift workers, which found that 37.5% of journeys after a night shift included a near crash event and drivers stopped driving due to excessive sleepiness in 43.8% of post-night shift drives (M. L. Lee et al., 2016). These findings are supported by driving performance post-night shift in Australian shiftworkers, with participants being significantly more likely to have sleep-related events, inattention related events, hazardous driving events, and driving violations post-night shift (Ftouni et al., 2013; Liang et al., 2019). Taken together, these findings demonstrate that shiftwork (often associated with working at night, working multiple shifts in a week, and working extended hours), leads to an increased likelihood of driving while fatigued, and therefore an increased risk of having a fatigue-related crash.

The likelihood of shift workers driving fatigued is also reflected within the grey literature. For example, a report from the Australian Co-operative Research Centre for Alertness, Safety, and Productivity (Howard et al., 2019) describes the findings of a study of heavy vehicle drivers working from 2015 – 2018. Findings indicated that shifts more than 12 hours duration resulted in a twofold increase in the likelihood of fatigue-related driving events. Similarly, the number of consecutive shifts, and shift timing (e.g., early morning and overnight shifts) resulted in poorer alertness while driving – suggesting that workers engaged in shift work schedules are likely to experience fatigue during these periods.

People with sleep disorders and other medical conditions: Several studies have investigated the impact of sleep disorders on the likelihood of driving while fatigued (Kalsi et al., 2018; Philip et al., 2010; Rizzo et al., 2019). These studies indicated that sleep disorders were associated with a higher prevalence of fatigue-related crashes and near misses. For example, in a survey of 350,004 drivers in France, the presence of a sleep disorder such as obstructive sleep apnoea, insomnia, or narcolepsy, was a significant predictor of a sleepiness-related crash (Philip et al., 2010). Similarly, in a study performed in Finland, when compared to drivers without sleep disorders, those with sleep disorders were reported significantly more amongst drivers who had been involved in a sleepiness-related crash (Kalsi et al., 2018). Obstructive sleep apnoea was also identified as a risk factor for driver fatigue in a Canadian study by Rizzo et al. (2019), in which drivers completed a questionnaire on driving violations. This study found that sleepiness was associated with increased driving violations for those with sleep apnoea compared to those without sleep apnoea. Taken together, these findings suggest that drivers diagnosed with sleep disorders may be at increased risk for fatigue-related vehicle crashes.

In a study of French drivers by Philip et al. (2015), drivers with Attention Deficit Hyperactivity Disorder (ADHD) reported significantly more sleepiness at the wheel compared to drivers without ADHD. It is important to note that those diagnosed with ADHD are also often diagnosed with a sleep disorder and experience excessive daytime sleepiness (Konofal et al., 2010; Schredl et al., 2007), and therefore it may be that the presence of a sleep disorder is leading to the increased risk of fatigued driving. This suggests that, amongst many at-risk groups, a greater likelihood of sleepiness during the day (either because of a sleep disorder or other health condition) can lead to a greater likelihood of driving while fatigued.

It has also been noted that a diagnosed sleep disorder is not necessarily the only medical or trait condition that may impact the likelihood of fatigued driving (Wolkow et al., 2019). For example, a recent review has discussed the notion that individual vulnerability to fatigue (based on sleep loss or a sleep disorder) may differ based on personal traits (e.g. being a morning or evening person) (Wolkow et al., 2019). Wolkow and colleagues also suggest road safety may be improved by increasing the degree of self-report and/or objective screening prior to driving. Furthermore, simply having a sleep disorder may not directly result in an increased risk – it is the symptoms of a sleep disorder (i.e., poor or shortened sleep) that are likely to result in this risk. In cases where a sleep disorder is treated or well managed – resulting in sufficient sleep of adequate quality – the likelihood of fatigued driving may be reduced (Filtness et al., 2011).

Professional drivers: Professional drivers (i.e., individuals who drive for work) are also an at risk-group for fatigued driving, with several studies highlighting the increased risk for these populations. Much of this research has focussed on heavy vehicle drivers and 'truck drivers' specifically (though specific definitions of what is considered a 'truck' are generally not included). A study by Zhang et al. (2016) was the only study found based on the search strategy that compared truck drivers with non-truck drivers. It was found that in a study of 394 crashes in China's Guangdong Province that were due to fatigue, truck drivers were significantly more likely to be involved than non-truck drivers. This increase in risk for truck drivers was also identified in samples of truck drivers from USA, where 47.1% of 593 truck drivers had fallen asleep at the wheel (McCartt et al., 2000), and in New Zealand, where in a sample of 130 truck drivers involved in crashes, 4.9% had fatigue identified as a contributing factor (Gander et al., 2006).

Heavy vehicle drivers have also been identified as an at-risk group for fatigued driving in the Australian context, with fatigued driving explored in a sample of 321 freight transport drivers (Friswell & Williamson, 2008). In this sample, 45% of drivers had nodded off while driving during the past 12 months and 91.7% of the drivers who did experience fatigue, attributed at least one potentially dangerous event while driving to fatigue.

Fatigue in public road transport drivers has also been investigated. Anund et al. (2016) found that 19% of Swedish city bus drivers reported having to fight to stay awake two to three times per week while driving. In a similar population in the UK, this proportion was 21% (Miller et al., 2020). Factors such as split shifts, operational factors, and shift timing have been identified as significant causes of fatigue in bus driving populations (Anund, Fors, et al., 2018; Pilkington-Cheney et al., 2020; Vennelle et al., 2010).

Two studies conducted in China have also identified taxi drivers as an at-risk group for fatigued driving (Li et al., 2019; Wang et al., 2019). In a study by Li et al. (2019), 58.7% of a sample of 269 taxi drivers reported frequent experiences with fatigued driving, and 75% of this sample were considered high-risk for fatigue-related crashes. Similarly, in a sample of 1,021 taxi drivers, sleepiness and fatigue while driving was significantly associated with an increased number of fatigue related errors (Wang et al., 2019). These findings suggest that taxi drivers could also be considered as an at-risk group for driver fatigue. However, it is important to note that these studies were both conducted in China and therefore the generalisability to other countries and other road types is unknown.

Future research should investigate the road safety of public road transport drivers in Australia and in a broader global context, given that fatigue related impairment could harm a passenger in addition to the driver.

The likelihood of fatigue-related crashes in professional drivers may be associated with driver demographics and some situational factors (Howard et al., 2004; Stevenson et al., 2013; Stevenson et al., 2010). For example, Howard et al. (2004) have shown that 59.6% of professional drivers in an Australian sample have sleep disordered breathing and 24.1% have chronic excessive sleepiness, both of which are associated with a greater likelihood of fatigue-related crashes. Additionally, crash likelihood in a sample of Australian heavy vehicle drivers was significantly higher during the circadian low period (midnight – 06:00 hrs), in addition to times when regular breaks were missed (Stevenson et al., 2013; Stevenson et al., 2010). However, sleep apnoea was not identified as a risk factor in this population. Research has also indicated that professional drivers (specifically heavy vehicle drivers) are more likely to report lower levels of sleepiness while driving – while having higher rates of long blinks and line crossings at night, and faster speeds overall (Anund, Ahlström, et al., 2018). This suggests that professional heavy vehicle drivers may underestimate their degree of fatigue-related performance impairment, thus potentially increasing the risk of both fatigued driving and fatigue-related crashes. Taken together, the studies performed on professional heavy vehicle drivers highlight the increased risk of fatigued driving seen in professional driving populations.

Information published within the grey literature also suggests that professional drivers are more likely to have a fatigue-related vehicle crash than other road users. A report published by the National Transport Safety Board (1995) indicates that fatigue was estimated to be a contributing factor in 31% of all crashes that included a heavy vehicle driver fatality. However, this is not supported by the information provided by the NSW Government (2017), which indicated that a significantly higher proportion of fatigue-related fatalities were in standard vehicles, as opposed to heavy vehicles.

New parents: New parents were identified as an at-risk group for driver fatigue (Armstrong et al., 2015; Livingstone et al., 2010; Malish et al., 2016). In one study performed by Malish, Arastu and O'Brien (2016) in the USA, 72 parents who had had a child in the last 12 months (92% mothers) completed a questionnaire on sleep and driving patterns. In this sample, 22.2% of drivers reported near-miss crashes, with 43.8% of these reported feeling very drowsy while driving. An Australian study using sleep and driving diaries also found that at six, 12, and 18 weeks post-birth, there was a high level of sleepiness seen during many drives – particularly overnight (Armstrong et al., 2015). Similarly, qualitative data combined with driving diaries indicated that high levels of sleepiness while driving is prevalent primarily in the first several months postpartum (MacKenzie, 2016). This is also reflected in qualitative reports of fatigued driving in a similar Australian population (Livingstone et al., 2010). Given the high levels of sleep loss/disruption and fatigue reported by new parents, further research into this population is warranted, to understand how the patterns of sleep and wake experienced by new parents (including fathers) impact driving outcomes.

Overview of at-risk groups: Much of the identified literature focussed on specific at-risk groups or comparisons between groups, rather than why these groups are at-risk. For example, shiftworkers (Härmä et al., 1998) and those with diagnosed sleep disorders are at greater risk for daytime sleepiness (Slater & Steier, 2012), and it is therefore unsurprising that they are at risk of driving while fatigued. However, it is likely that there are several factors that increase the risk of fatigued driving for these groups, and these are likely to be organisational, environmental, or individual factors, rather than group-level factors (i.e. it is factors that impact those populations that is likely to result in fatigue, rather than membership of a population per se). For example, while a shiftworker is perhaps more likely to have extended time awake than a traditional dayworker due to their shift schedule, if a non-shiftworker was to stay awake for an extended period they would be at risk of fatigued driving. Similarly, new parents are also likely to have disrupted sleep due to their newborn (Malish et al., 2016), which leads to increased sleepiness during the day and is therefore likely to contribute to elevated risk of driver fatigue. In the case of both new parents and shift workers, it is external factors (e.g., shift timing or overnight waking due to an infant) that impact sleep and therefore fatigue. As a result, any individual who had similar sleep/wake schedules to members of these two groups may be similarly likely to experience fatigue while driving. Regardless, the understanding that certain populations are more likely to drive while fatigued (and therefore are at greater risk of a fatigue-related crash) allows for targeted research and interventions to improve these outcomes.

It is also important to note that this list is likely not exhaustive, as no studies were identified that suggested specific groups not at risk of fatigued driving. Also, of note, many studies included in this review did not include a comparison group, for example Scott et al. (2007) found that nurses were at-risk for drowsy driving, however no comparison was made to the fatigued driving of other groups. Further, taxi drivers were identified as a group at-risk for fatigued driving (Li et al., 2019; Wang et al., 2019), but were not compared with non-taxi drivers. They were likely chosen as a sample of interest for driving fatigue due to the frequency of driving and the likelihood of having a passenger in the vehicle. The methodology of many of these studies means that the objective comparison of risk cannot be evaluated.

In summary, the existing scientific literature highlights several groups that are at elevated risk of fatigue-related crashes. These groups include: 1) younger drivers; 2) male drivers; 3) shiftworkers; 4) drivers with sleep disorders or medical conditions; 5) professional drivers; and 6) new parents. Whilst fatigue-related crashes are not restricted to these groups alone, the higher prevalence of fatigue-related crashes in these groups does suggest that they may be worthwhile targets for specific interventions aimed at reducing the occurrence of fatigue-related crashes.

Do drivers know they are fatigued, and if so – do they choose to stop driving?

Just one study within the relevant date range has directly investigated the degree of awareness that drivers have of their own fatigue and associated crash risk specifically (Williamson et al., 2014). Drivers were asked to rate their likelihood of falling asleep during a two-hour simulator drive task. Drivers who rated themselves as likely to fall asleep, had crash rates that were four times higher than other participants. These ratings were performed during the drive, and were temporally close to the crash times, suggesting that drivers have a degree of capacity to predict their own sleepiness and associated crash risk.

A number of other studies demonstrate that subjective sleepiness can predict aspects of driving performance (rather than crash likelihood), with subjective ratings of sleepiness consistently correlating to driving performance and objective measures of sleep (Åkerstedt et al., 2013; Ingre, Åkerstedt, Peters, Anund, & Kecklund, 2006; Jiang et al., 2017; Jones et al., 2006; Kosmadopoulos et al., 2017; Schreier et al., 2015; Wang et al., 2018). For example, in the study by Ingre, Åkerstedt, Peters, Anund, Kecklund, et al. (2006) conducted in Sweden, 10 shiftworkers completed a two-hour drive after a normal night of sleep and after a nightshift. There was increased crash risk after the nightshift, which corresponded to increases in subjective sleepiness and suggests that participants were aware of their fatigue levels when driving. Further, drivers have signalled they were sleepy and prematurely terminated the drive (Åkerstedt et al., 2013; Ingre, Åkerstedt, Peters, Anund, Kecklund, et al., 2006), suggesting an awareness of subjective fatigue and a willingness to stop driving when fatigued. However, it is important to note that these were experimental studies with participants driving on a controlled driving track and thus drivers were able to stop when fatigued. In the real world, drivers may keep driving when fatigued due to workplace pressure, desire to get home, or a lack of a safe place to stop (Nordbakke & Sagberg, 2007; Thompson et al., 2015).

A relationship between objective and subjective measures of sleepiness has been reported in relation to driving. Higher subjective sleepiness was associated with longer blink duration, indicating sleepiness, and greater lane variability on a driving task, indicating sleepiness-related driving impairment (Ingre, Åkerstedt, Peters, Anund, Kecklund, et al., 2006). Similar results were found in a study performed by Wang et al. (2018), in which 36 truck drivers in China completed two to six hour drives. Furthermore, high sleepiness ratings in shift workers (Karolinska Sleepiness Scale[3] scores > 6) were associated with being 2.6 times more likely to have an adverse event while driving home following an extended shift (Anderson et al., 2018). The relationship between sleepiness and driving performance impairment has also been shown post-night shift, with subjective sleepiness increasing during drive time, and all near misses occurring after 45 minutes of driving (M. L. Lee et al., 2016). Similarly, Ftouni et al. (2013) found strong associations between subjective sleepiness, objective drowsiness, and the likelihood of adverse driving events in a shift working nurse population, This lends further evidence to the idea that subjective fatigue correlates with objective fatigue. However, these were also experimental studies in which drivers were asked their levels of subjective fatigue, and drivers in the real-world may not be as likely to reflect on their level of fatigue while driving when not asked directly, and therefore may not stop and rest when needed. There is evidence to suggest that drivers may find it easier to judge sleepiness based on symptoms (e.g. yawning, heavy eyes) rather than via the use of a validated scale (e.g. the Karolinska Sleepiness Scale) (Filtness et al., 2014; Howard et al., 2014). Together, findings from the identified literature suggest that, overall, drivers are aware of their fatigue. While drivers may not know **precisely** when they will fall asleep, it is fair to conclude that they are good at determining whether they are increasingly fatigued – and as such be aware that the risk of falling asleep is higher (Rajaratnam & Jones, 2004).

There is evidence that drivers continue to drive even when they know they are fatigued (Nordbakke & Sagberg, 2007; Rajaratnam & Jones, 2004; Thompson et al., 2015). The identified studies all utilised questionnaire or interview methods to investigate the willingness to drive when fatigued and the factors that were likely to influence decision-making. For example, in a study by Nordbakke and Sagberg (2007) a driving attitudes questionnaire completed by 1,513 drivers in Norway revealed that although drivers had good knowledge of the factors influencing the risk of falling asleep while driving and of various countermeasures, most drivers continued to drive when they recognised they were sleepy. The factors that increase the likelihood of continuing to drive while sleepy include older age,

[3] The Karolinska Sleepiness Scale is a nine-point scale with anchors from 'extremely alert' to 'very sleepy, great effort keeping awake, fighting sleep'.

perceived confidence in driving ability, poor sleep quality, a shorter trip, running late, going to an appointment, or being male (Jiang et al., 2017; C. J. Lee et al., 2016; Nordbakke & Sagberg, 2007; Obst et al., 2011; Paterson et al., 2016; Watling et al., 2014; Watling et al., 2015).

One Australian study investigated motivational factors for continuing to drive while sleepy, and determined that age, sex, motivation, and risk perception are associated with continuing to drive, even when drivers recognise they are sleepy (Watling et al., 2014). Other evidence suggests that younger drivers were more likely to drive while tired than other drivers, reflecting a higher degree of acceptance of risky driving behaviours in this population (Watling, 2020). It must be noted, however, that a recent worldwide survey indicated that less than 3% of drivers in all countries surveyed found driving while fatigued to be personally acceptable (SWOV Institute for Road Safety Research, 2019). Together, these findings suggest that although drivers may be able to accurately perceive their fatigue levels and have awareness of the dangers of fatigue when driving, this does not necessarily lead to safe driving behaviour given external factors, such as running late to an appointment or financial pressures. It may be that although drivers can recognise the symptoms of sleepiness while driving, they may not consider the potentially catastrophic consequences of continuing to drive, or the likelihood of a fatigue-related crash. As such, fatigued drivers may expect that 'it won't happen to me'.

In summary, given the common occurrence of fatigue, strategies to address the contribution of fatigue to vehicle crashes need to include a focus on driver behaviour, in particular the decision to drive while fatigued. While the scientific literature suggests we are more often than not able to identify when we are fatigued, the general consensus is that the decision to continue to drive whilst fatigued may well be the most appropriate point to target behavioural change interventions.

Managing the Risks of Fatigue and Driving

Managing fatigue through legal and regulatory frameworks

Introduction: scope, approach and methods

This section of the review provides an overview of the primary legislative, regulatory, and policy frameworks that relate to fatigue and driving in Australia, with reference to differences in approaches taken in international jurisdictions. The purpose of this part of the review is to provide a snapshot of current approaches adopted in Australia, identify the primary mechanisms used within these frameworks to influence safe driving behaviours with respect to fatigue, and identify opportunities for future enhancement.

This section begins with an overview of Australian criminal and road traffic law with respect to the management of the risks associated with fatigue and driving that apply to all road user groups. This overview is not meant to serve as a comprehensive legal review, but rather provide an overview of the relevant legislation. This section is written from the perspective of fatigue risk management, and not from the perspective of a fine-grained review of prosecution processes and outcomes or highly nuanced legal arguments. The aim is to provide the lay-reader with a clear overview of the primary legal mechanisms currently used to manage fatigue and driving across Australian jurisdictions and identify the strengths and weaknesses of these current legal mechanisms with respect to managing the risks associated with fatigue and driving. The general legal approach to fatigued driving taken in Australia is then contrasted with different approaches taken in international jurisdictions, based on the findings of a literature search relating to international legal frameworks and fatigued driving.

The review then turns to examine the approach adopted in National Heavy Vehicle Law and Regulation in Australia with respect to managing fatigue and driving. This section of the review draws out the differences in approaches adopted in the context of professional heavy-vehicle driving operations, and examines how a move towards a risk-based approach to fatigue management in this sector has informed recent regulatory reforms adopted in the majority of Australian states and territories for heavy vehicles.

Next, the review provides an overview of work health and safety law and regulation in Australian states and territories, as it relates to fatigue and driving from an occupational perspective. The need for organisations to adopt a pro-active risk-based approach to the management of fatigue and driving is highlighted, in addition to some general principles drawn from recent legal, workers compensation decisions, and coronial findings.

Finally, this section of the review provides a snapshot of the wide cross-section of policy frameworks that relate to fatigue and driving. Based on engagement with key stakeholders, a range of publicly available policy documents were reviewed to highlight the role these documents play in the broader context of managing the risks associated with fatigue and driving.

Legislation relating to road safety

Across all states and territories in Australia, legislation relating to driving plays an important role in road safety. However, our desktop review of Australian state and territory legislation, as at June 2021, demonstrated that there is no single offence for fatigued driving. Further, different forms of legislation approach fatigue-driving from quite different perspectives. A *reactive* focus is taken by criminal and road traffic law where fatigue is identified as a factor in impaired driving resulting in a road crash. In contrast, work health and safety, transportation, and national heavy vehicle legislative frameworks take a more *proactive* focus on fatigue as an identifiable hazard and strategies associated with effective mitigation of fatigue-related risk.

The review of Australian legislation identified that in most states and territories, the following legislative frameworks are relevant in terms of fatigued driving:

- criminal and road traffic law (with a focus on dangerous/reckless/culpable driving)
- civil law (with a focus on negligence)
- work health and safety law (with a focus on identifying and managing work-related safety risks)
- transportation law (with a focus on passenger safety)
- national heavy vehicle law (with a focus on road transport and heavy vehicles)

Similarly, the model Australian Road Rules (ARR), set out by the National Transport Commission and adapted as elements of state and territory legislation, do not make any specific reference to fatigued driving, nor do they refer to driver impairment or ensuring driver is in a fit state to drive.

Legislation Relating to Culpable Driving

In Australian law, matters relating to culpable forms of driving, such as negligent, reckless or dangerous driving, are set out in relevant state or territory legislation. While there are some minor differences between jurisdictions, the general principles relating to the ways in which culpable driving is dealt with are consistent. That is to say, fatigue is seen as a factor that *contributes* to acts of culpable driving which are defined as offences under the relevant legislation.

Driving offences are dealt with under either general crimes / criminal offences law, road traffic law, or both. The general provisions under this legislation can be summarised as follows:

> **Crimes / Criminal Offences Acts:** Situations where death or serious injury has resulted from a road traffic crash, driving offences and penalties are set out in general crimes / criminal offences legislation. Under these acts, the most serious instances of culpable driving may result in a charge of manslaughter. Also, under these acts, offences such as culpable driving causing death or dangerous driving causing death or serious injury are specified.
>
> **Road Traffic Acts**: In most states and territories, driving offences relating to dangerous or careless driving are set out in specific acts relating to road use and driving. In many instances, offences under these acts are considered less serious than those dealt with under the crimes / criminal offences acts.

An overview of the Australian state and territory legislation relating to culpable driving offences is provided in Table 1.

Table 1: Overview of Relevant Legislation in Australian States

State / Territory	Relevant Legislation	Offences
Australian Capital Territory	*Crimes Act 1900* (ACT) *Road Transport (Safety and Traffic Management) Act 1999* (ACT)	s 15 Manslaughter s 29 Culpable driving of a motor vehicle s 6 Negligent Driving s 7 Furious, reckless or dangerous driving
New South Wales	*Crimes Act 1900* (NSW) *Road Transport Act 2013* (NSW)	s 18 Manslaughter s 52A Dangerous driving: substantive matters s 117 Negligent, furious or dangerous driving
Northern Territory	*Criminal Code Act 1983* (NT) *Traffic Act 1987* (NT)	s 160 Manslaughter s 174 Driving motor vehicle causing death or serious harm s 30 Dangerous driving
Queensland	*Queensland Criminal Code 1899* (Qld) *Transport Operations (Road Use Management) Act 1995* (Qld)	s 303 Manslaughter s 328A Dangerous Operation of a Vehicle s 83 Careless Driving
South Australia	*Criminal Law Consolidation Act 1935* (SA) *Road Traffic Act 1961* (SA)	s 13 Manslaughter s 19A—Causing death or harm by use of vehicle or vessel s 45 Careless Driving s 46 Reckless or Dangerous Driving
Tasmania	*Criminal Code Act 1924* (Tas) *Traffic Act 1925* (Tas)	s 156 Culpable Homicide s 159 Manslaughter s 167A Causing death by dangerous driving s 167B Dangerous driving causing grievous bodily harm s 32 Reckless Driving
Victoria	*Crimes Act 1958* (vic) *Road Safety Act 1986* (Vic)	s 5 Manslaughter s 318 Culpable driving causing death s 319 Dangerous driving causing death or serious injury s 64 Dangerous Driving s 65 Careless Driving
Western Australia	*Criminal Code Act Compilation Act 1913* (WA) *Road Traffic Act 1974* (WA)	s 280 Manslaughter s 59 Dangerous driving causing death or grievous bodily harm s 59A Dangerous driving causing bodily harm s 59BA Careless driving causing death, grievous bodily harm or bodily harm s 60 Driving in a reckless manner s 61 Dangerous driving

The legal framework with respect to culpable driving in Victoria provides a good example of the way in which fatigued driving is generally dealt with from the perspective of Australian criminal law. The *Crimes Act 1958* (Vic) sets out in div 9, driving offences connected with motor vehicles. Section 318 of the Act deals with the offence of Culpable driving causing death. This section states:[4]

> *(1) Any person who by the culpable driving of a motor vehicle causes the death of another person shall be guilty of an indictable offence and shall be liable to level 3 imprisonment (20 years maximum) or a level 3 fine or both.*
>
> *(2) For the purposes of subsection (1) a person drives a motor vehicle culpably if he drives the motor vehicle—*
>
> *(a) recklessly, that is to say, if he consciously and unjustifiably disregards a substantial risk that the death of another person or the infliction of grievous bodily harm upon another person may result from his driving; or*
>
> *(b) negligently, that is to say, if he fails unjustifiably and to a gross degree to observe the standard of care which a reasonable man would have observed in all the circumstances of the case; or*
>
> *(c) whilst under the influence of alcohol to such an extent as to be incapable of having proper control of the motor vehicle; or*
>
> *(d) whilst under the influence of a drug to such an extent as to be incapable of having proper control of the motor vehicle.*
>
> *(2A) Without limiting subsection (2)(b), negligence within the meaning of that subsection may be established by proving that—*
>
> *(a) a person drove a motor vehicle when fatigued to such an extent that he or she knew, or ought to have known, that there was an appreciable risk of him or her falling asleep while driving or of losing control of the vehicle; and*
>
> *(b) by so driving the motor vehicle the person failed unjustifiably and to a gross degree to observe the standard of care which a reasonable person would have observed in all the circumstances of the case.*

The specific reference to fatigue made in s 318 (2A) of the Act is a relatively recent addition, being included in 2004. Of all the relevant Australian legislation, this is the most explicit reference to fatigue as establishing negligence. However, across all Australian criminal legislation there is no specific offence created simply by virtue of driving whilst fatigued. Rather, the offence is created by virtue of objective driving actions that are deemed culpable, variously in terms of dangerous, careless, negligent or reckless driving. This feature of Australian law has remained the case for some time (Jones et al., 2005).

Even though there is longstanding scientific evidence that fatigue-related impairment presents a serious risk in terms of road crashes (Horne & Reyner, 1999), driving whilst in a state of fatigue is not an offence as such in Australia. This approach to fatigue is markedly different to the way in which Australian road traffic legislation deals with other sources of impairment, such as drug and alcohol intoxication, whereby drivers commit an offence if they exceed a prescribed blood alcohol concentration or are detected with a prescribed drug in their system, regardless of the impact this might have on their driving.

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[4] *Crimes Act 1958* (Vic) s 318

Civil law and fatigued driving

In addition to potential criminal responsibility in the form of offences relating to culpable driving, a road crash caused by fatigued driving may lead to civil liability in the tort of negligence. Tort law is built on the basic premise that there are community standards of acceptable behaviour and duties of care, and an individual who acts outside those standards, and in doing so causes damage, harm or loss to another shall be held legally responsible for compensating for that loss (Barker et al., 2012).

Within this context, driving whilst impaired by fatigue is generally considered outside community standards of acceptable behaviour. Driving a vehicle involves a duty of care to drive in a safe manner, whilst not impaired by factor such as fatigue. Just as fatigued driving cannot be used as a defence in criminal law, for many years it has been established that fatigue cannot be used as a factor in civil law to reduce liability (Jones et al., 2003). To this end, fatigued driving that results in a crash causing harm or loss is deemed negligent behaviour and those responsible may be found liable.

Evaluation of the effectiveness of criminal and civil legislation in Australia

There is little evidence to suggest that culpable driving legislation in Australia is effective in terms of reducing the incidence of fatigued driving. In general terms, the primary functions of criminal law are to define unacceptable forms of behaviour, apportion appropriate punishment to those who perform unacceptable forms of behaviour, but also importantly to provide a *general deterrent* against unacceptable forms of behaviour to the general public at large. However, the degree to which even widely publicised prosecutions have achieved the goal of general deterrence in relation to fatigue and driving is not well established. In a recent study of Australian drivers, 70% (n=1,060) reported that they had continued to drive when sleepy (Watling et al., 2015). Furthermore, of the few studies that have evaluated the effectiveness of criminal law in reducing the incidence of fatigued driving, there is consistent evidence to suggest individuals view fatigued driving as significantly less culpable than driving under the influence of alcohol (Williams et al., 2012) and the seriousness of driver fatigue is under-recognised by the general public (Jones et al., 2010).

Just as is the case with respect to the effectiveness of criminal law on fatigued driving, there is little evidence to suggest that civil law has a significant deterrent effect with respect to fatigued driving. It could be suggested that while civil law does play an important role with respect to determinations of negligence and liability and therefore provides appropriate mechanisms for compensation, the impact of such laws on changing drivers attitudes and behaviours is negligible in a similar way to criminal law (Watling, 2018). It is important to note that the risk 'assessment' undertaken by individuals who engage in drink and drug driving likely involves the perception that getting caught is unlikely though possible. In the case of fatigue and driving, it is well known that there is no mechanism by which one can be 'caught' fatigued driving in the absence of a crash (Salmon et al., 2019). This should be considered an important gap in current legal approaches to fatigued driving.

International perspectives on criminal law

Most jurisdictions world-wide have similar approaches to Australia in that driving whilst fatigued is not expressly an offence. Rather, it is only when fatigue objectively results in culpable driving, and generally only when a crash occurs, that the potential for fatigue-related impairment is closely examined.

In the UK, a similar legal framework exists in relation to fatigue and driving law as is found in Australia. If a crash results from fatigued driving, offences such as dangerous driving and careless driving exist under the *Road Traffic Act 1988* (UK). Such offences operate in a similar manner to Australia and come with similar forms of penalty if found guilty of an offence, with both imprisonment and loss of drivers' licence potential outcomes. In the UK, as in Australia, driving whilst fatigued, such that the driver was aware of the risk of falling asleep has formed important elements of culpable driving prosecutions (Rajaratnam & Jones, 2004).

In addition to the offences under the *Road Traffic Act 1988* (UK) in the UK, there is also a set of less formal rules set out in the *UK Highway Code*. The *UK Highway Code* is a set of general rules that govern safe use of roads by all road users. Some of the rules in the code are legal requirements, and non-compliance is a criminal offence under a range of different pieces of legislation (e.g. the *Motor Vehicles (Driving Licenses) Regulations 1999* (UK) and the *Road Vehicles (Construction and Use) Regulations 1986* (UK). Other rules are largely advisory in nature, but failure to comply can be used as evidence to establish liability under relevant traffic acts. With respect to fatigue, Rule 90 of the *UK Highway Code* refers to the requirement to report any health condition that is likely to affect driving. This refers to a specific legal requirement under the *Road Traffic Act 1988* (UK) and would include a range of sleep disorders such as Obstructive Sleep Apnoea. Rule 91 of the *UK Highway Code* then refers to general principles to avoid driving when tired. These are not specific legal requirements but would be used to inform evidence for offences of dangerous or careless driving under the Act. No such equivalent guidance is provided in the *Australian Road Rules*, even though in many respects the Australian general road rules reflect much of the content of the *UK Highway Code*. Furthermore, there is similar potential liability for employers in the UK as in Australia if an employee has a fatigue-related crash while driving in the course of their employment.

There are several jurisdictions worldwide where alternative approaches provide examples of more specific legislative mechanisms for reducing the risk of driving whilst impaired by fatigue (see Table 2). In Finland, the *Road Traffic Act 2020* (Finland) sets out that driving whilst impaired by fatigue is an offence in and of itself, amongst other factors that can impair driving performance. The Act states in s 17 that 'a vehicle must not be driven by a person who is impaired, due to illness, defect, injury, fatigue or intoxication or for any other similar reason'.[5] Driver fatigue is also dealt with in similar fashion across the traffic laws in the other Nordic countries of Denmark, Norway and Sweden (Radun et al., 2012).

In the USA state of New Jersey, a law was passed in 2003 that for the first time set out a clear definition of fatigue in the context of driving law. Named after a college student Maggie McDonnell, who was killed by a driver who had fallen asleep at the wheel after 30 hours of wakefulness, 'Maggie's Law' was passed to fill a significant gap in legislation whereby fatigue-related impairment was not considered as being associated with culpability for deaths or serious injuries associated with road traffic crashes. Under this law, a person who causes death by driving whilst 'knowingly fatigued' can be convicted for vehicular homicide and subjected to lengthy prison sentence. Further, under this law, 'fatigue' is simply and objectively defined as 'having been without sleep for a period in excess of 24 consecutive hours'.[6]

[5] *Road Traffic Act 2020* (Finland)

[6] *Maggie's Law: National Drowsy Driving Act of 2003. New Jersey State 2C: 11-5*

Table 2. Examples of International Legislation Relevant to Driver Fatigue

Country	Relevant laws and regulations	Offences	Similarities and Differences from Australian Legal Frameworks
New Zealand	*Crimes (Dangerous Driving) Act 2004* (NZ)	Death by dangerous driving	Broad similarities with Australian legislation in terms of culpable driving offences and penalties.
United Kingdom	*Road Traffic Act 1988* (UK) *Motor Vehicles (Driving Licenses) Regulations 1999* (UK) *Road Vehicles (Construction and Use) Regulations 1986* (UK)	Dangerous driving	Broad similarities with Australian legislation in terms of culpable driving offences and penalties.
	UK Highway Code	Rule 90 – Health-related impairment Rule 91 – Driving whilst tired.	Whilst these rules do not set out specific offences, they can be used to guide the prosecution of dangerous driving offences, and explicitly identify road user's duties to not drive whilst impaired by fatigue.
United States of America	*Maggie's Law: National Drowsy Driving Act of 2003. New Jersey State 2C: 11-5* *SB 874 (2013) – Arkansas, USA*	Vehicular homicide Negligent homicide (if awake for >24h)	These two state laws set out explicitly that driiving having been awake for more than 24 hours and causing a fatal accident shall be considered as a homicide, with significantly increased penalties associated with the offence than general death by dangerous driving offences.
Finland	*Road Traffic Act 2020* (Finland)	Article 63 – Offence to Drive Whilst Fatigued	Finnish road traffic law sets out explicitly that driving while impaired by fatigue is an offence.

Evaluation of the effectiveness of criminal and civil legislation outside Australia

As is the case with respect to Australian legislation, there is little evidence to suggest that the different approaches to culpable driving legislation outside Australia are significantly more effective in terms of reducing the incidence of fatigued driving.

For instance, Maggie's Law has been criticised as not offering an appropriate form of risk mitigation in terms of fatigue and driving, by having a too-narrow definition of fatigue and positioning fatigue as a criminal offence only for the rare circumstance of a fatal crash (Radun et al., 2012). The law defines fatigue in terms of excessive wakefulness, which is a very narrow definition that does not take into consideration other sources of fatigue-related impairment such as cumulative sleep debt and circadian disruption. This narrow definition illustrates a need to better define fatigue from a legal perspective in simple, objective, and measurable terms.

Whilst provisions that explicitly identify driving whilst fatigued as an offence have been in place in some jurisdictions like Finland for well over a decade, they are subject to difficulties with respect to enforcement and prosecution (Radun et al., 2013). Typically, such laws can only be enforced by way of prosecution after a crash has occurred. There are no real mechanisms by which fatigue-related impairment can be ascertained prior to significant outcomes in terms of evidence of dangerous driving. Perhaps more importantly, there is also evidence to suggest that drivers frequently break the laws that set out driving whilst fatigued as an offence (Radun et al., 2013). The lack of roadside enforceability and cultural norms associated with factors such as shiftwork are thought to contribute.

Even if more jurisdictions took the approach seen in Finland and other Scandinavian countries that set out driving whilst fatigued as an explicit offence, the lack of roadside testing for fatigue effectively rules out enforcement as a viable option in the short term. Unlike roadside testing for alcohol and other drugs, it is not currently possible to ascertain that a driver is fatigued during a routine traffic stop. Even in the case of a crash, it can be difficult to definitively determine if fatigue was a causal factor – as described above.

Issues relating to civil liberties, over-regulation and the fairness of law are important considerations requiring significant policy development work prior to legal reform.

Legislation relating to commercial and heavy vehicles in Australia

National Heavy Vehicle Law and Regulation

At law, fatigue and driving are comprehensively managed within the Australian road transport industry through the Heavy Vehicle National Law for heavy vehicles over 4.5 tonnes gross vehicle mass. The Heavy Vehicle National Law, and its regulations, is administered by the Australian National Heavy Vehicle Regulator (NHVR).

The Heavy Vehicle National Law was enacted in all states and territories (except Western Australia and the Northern Territory) in 2014, and the default model legislation and regulations have been adopted as state and territory law with only minor modifications between jurisdictions. Although the Heavy Vehicle National Law has not been adopted in WA or the NT, any vehicles and drivers operating out of these jurisdictions must comply with the Heavy Vehicle National Law when they cross into one of the states or territories where the Heavy Vehicle National Law applies. For the purposes of this review, we will use South Australia's adoption of the model legislation for reference.

Unlike the generic provisions relating to dangerous or careless driving in the criminal codes and road traffic acts in Australia, the Heavy Vehicle National Law sets out very clearly that driving whilst impaired by fatigue is an offence. The main purpose of Chapter 6 within this legislation is explicitly described as 'to provide for the safe management of the fatigue of drivers of fatigue-regulated heavy vehicles while they are driving on a road'. To this end, Part 6.2 of the *Heavy Vehicle National Law (South Australia) Act 2013* (SA)[7] sets out a range of duties relating to fatigue and driving. Section 228(1) of the Act states that '*a person must not drive a fatigue-regulated heavy vehicle on a road while the person is impaired by fatigue'*. Further, s 226 of the Act sets out matters that a court might consider in deciding whether a person was impaired by fatigue, which include:

> *(a) any relevant cause of fatigue or sign of fatigue that was evident, and the degree to which it may indicate that the driver was impaired by fatigue;*
>
> *(b) any behaviour exhibited by the driver that may have resulted from the driver being impaired by fatigue; (such as)*
>
> - *the circumstances of any incident, crash or near miss*
> - *poor driving judgement*
> - *inattentive driving such as drifting into other lanes on a road or not changing gears smoothly*
>
> *(c) the nature and extent of any physical or mental exertion by the driver; and*
>
> *(d) whether the driver was in breach of the driver's work and rest hours option.*

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[7] *Heavy Vehicle National Law (South Australia) Act 2013* (SA) s 226, s 228, used here an exemplar of the national model law.

The primary mechanism to manage fatigue under the Heavy Vehicle National Law is a series of *hours of work* limitations set out in the model Heavy Vehicle (Fatigue Management) National Regulation, as enacted in South Australia by virtue of s 5 of the *Heavy Vehicle National Law (South Australia) Act 2013* (SA)[8]. This type of approach, that limits the number of hours that can be worked, and sets out minimum requirements for rest breaks is a common feature of the traditional approach to fatigue management in many industries such as mining and rail (Dawson & McCulloch, 2005). Under the Heavy Vehicle (Fatigue Management) National Regulation, drivers are required to keep work diaries detailing their hours of work and rest to demonstrate compliance.

Within the Heavy Vehicle (Fatigue Management) National Regulation, a set of four different work and rest hours options are provided as follows:

1) ***Standard hours*** – a set of conservative maximum work and minimum rest hours for different driving types (solo drivers, solo-drivers of busses, two-up driving). An example set of standard hours is provided in Table 3;
2) ***Basic Fatigue Management (BFM)*** – a less restrictive set of maximum work and minimum rest hours for accredited operators that can be accessed by meeting requirements for additional fatigue risk management through processes such as fitness for duty monitoring, additional driver training, and other forms of risk mitigation;
3) ***Advanced Fatigue Management (AFM)*** –provides flexible work and rest arrangements to operators who adopt a risk management approach to managing driver fatigue. In AFM as an operator, you must be able to demonstrate an understanding of the risks associated with hours of work arrangements, and can demonstrate specific forms of risk mitigation to ensure safe operations within these hours; and
4) ***Exemptions*** – made available predominantly to emergency services organisations.

Each of these work and rest hour options set out maximum work time and minimum rest requirements for drivers, which differ as a function of transport type (goods or passengers) and the number of drivers in each vehicle. An example of these work and rest hour options (for solo drivers of a fatigue-regulated heavy vehicle) is provided in Table 3.

[8] The South Australian Law is used here as an exemplar of the model national law, but these provisions relate equally to other jurisdictions that have enacted the model national legislation.

Table 3. Standard hours for Solo Drivers from Heavy Vehicle (Fatigue Management) National Regulation

In any period of…	*A driver must not work for more than…*	*A driver must not rest less than..*
5 ½ hours	5 ¼ hours work time	15 continuous minutes rest time
8 hours	7 ½ hours work time	30 minutes rest time in blocks of 15 continuous minutes
11 hours	10 hours work time	60 minutes rest time in blocks of 15 continuous minutes
24 hours	12 hours work time	7 continuous hours stationary rest time*
7 days	72 hours work time	24 continuous hours stationary rest time
14 days	144 hours work time	2 x night rest breaks# and 2 x night rest breaks taken on consecutive day

*Stationary rest time is the time a driver spends out of a heavy vehicle or in an approved sleeper berth of a stationary heavy vehicle. #Night rest breaks are seven continuous hours stationary rest time taken between the hours of 22:00 hrs on a day and 08:00 hrs on the next day (using the time zone of the base of the driver) or a 24 continuous hours stationary rest break.

Another important consideration embedded within the Australian National Heavy Vehicle Law and Regulations is that of "chain of responsibility". This approach adopts a more wholistic view of duties to ensure safety across the whole of the road transport supply chain. Chain of responsibility regulations place the burden of managing fatigue on all levels of the supply chain (e.g. management, drivers, clients, etc.). This is with a view to ensuring no parties within the supply-chain inappropriately divest their responsibility for fatigue management, in addition to reducing time pressures associated with heavy vehicle driver duties (Department of Transport and Main Roads & Queensland Government, 2018). This approach is considered unique to Australia and New Zealand and has not been applied by other countries (Van Der Westhuizen, 2018).

In general, the provisions of the National Heavy Vehicle Law and Regulations offer a sliding scale of approaches to fatigue risk management, from simple prescriptive hours or work and rest limitations through to more sophisticated risk-based approaches (Gander, 2015). Smaller operators with limited resources are able to adopt a simple compliance-based approach, while larger operators with the ability to integrate fatigue into broader safety management systems focussed around hazard identification and risk management are provided the flexibility to work tailored hours of work and rest periods with additional forms of fatigue risk mitigation.

International perspectives on commercial road transport law

In many respects, the risk-based approach to the management of fatigue that is found in the Australian heavy vehicle context, at least for the more advanced options under Australian National Heavy Vehicle Law and Regulations, is world-leading. By affording alternative flexible options to operators who instigate more sophisticated approaches to fatigue management, and through the Chain of Responsibility provisions, the Australian commercial road transport approach adopts a pro-active and risk-based approach to fatigue management. This is in line with more general provisions relating to safety management and work health and safety as will be discussed in the following section.

In the majority of other similar jurisdictions worldwide, the management of commercial vehicle driver fatigue rests on compliance with prescriptive hours or work and rest limitations set out in relevant legislation. For instance, in the US, Part 395 of the Federal Motor Carrier Safety Regulations (FMCSR)[9] sets out prescriptive limits for the Hours of Service of Drivers. This serves as the primary mechanism to manage driver fatigue for commercial vehicles in the US. Similarly, in New Zealand, Canada and across Europe, prescriptive limits on driving hours and rest requirements are also used as the primary mechanism to manage driver fatigue (Gander et al., 2011).

Evaluation of the effectiveness of commercial road transport law

Overall, literature examining fatigue risk management in the heavy vehicle industry suggests that the range of regulatory mechanisms described above provide significant benefits in terms of safety (Burke et al., 2016) However, shortcomings of traditional HoS approaches have also been highlighted in the literature (Anderson et al., 2017; Gander et al., 2011; Lerman et al., 2012). For instance, one USA study observed no decrease in crash rate after the introduction of a driving hours limitation that restricted drivers to one 'restart' per week. In this context, a 'restart' period allows truck drivers to reset their duty time log back to zero. It must be a minimum of 34 consecutive hours free of work and must span two consecutive periods between 1:00am to 5:00am (Anderson et al., 2017). The observation that there was no change in crash rate after instituting this limitation suggests that, for professional drivers, there may be factors other than HoS that are leading to fatigue.

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[9] *Federal Motor Carrier Safety Regulations* (US) p 395

Even though there is not always consistent evidence that all HoS limitations result in effective fatigue management, on balance it must be accepted that in general, HoS limitations do have some impact on reducing the risk of fatigue-related vehicle crashes. This being the case, learnings from HoS limitations may be helpful, in combination with other strategies, to reduce fatigue and fatigue-related crashes for light vehicle drivers, and heavy vehicle drivers who are not currently covered under legislation (e.g. those who drive only within 100km of their base location, etc.). This is because fatigue is similarly experienced by these populations of drivers (e.g. city bus drivers, taxi drivers, non-professional drivers, etc.) (Anund et al., 2016; Friswell & Williamson, 2008; Li et al., 2019; Miller et al., 2020).

Beyond the inherent limitations of HoS approaches to fatigue management, compliance with HoS limits themselves also remain an issue. Two studies of professional long-haul drivers assessed the effectiveness of HoS through subjective reports of drivers (in the USA and Australia, respectively) (Kemp et al., 2013; Mayhew & Quinlan, 2006). HoS limitations are based on the understanding that extended work hours are a contributing factor to fatigue, and that limiting these hours will allow employees to have adequate time to rest. The studies demonstrated that although drivers were aware of the limitations, there were certain factors and circumstances, such as economic pressure to complete a job, that led to drivers exceeding their HoS limitations. This issue exists in other industries (e.g. mining, manufacturing), as productivity requirements and employees' earning potential can lead to overtime work, skipping breaks, working extended hours, and back to back shifts, regardless of the HoS limitations (Honn et al., 2019). The frequency of drivers detected for breaches of driving and rest hour limits highlights that this issue is indeed relevant for Australia, and is only likely to be effectively addressed through continuing education, enforcement and most importantly long-term cultural change (Williamson & Friswell, 2019).

While some learnings from the heavy vehicle industries may be applicable to non-professional drivers, there are differences that must be considered. For example, in the study by Adyatama et al. (2019) in Indonesia, a model was used to predict fatigue based on sleep duration in a sample of dump truck drivers. While such a model may be useful for light vehicle drivers, workload was a key input to the model. Differences in workload between light and heavy vehicle drivers may limit the generalisability of findings between the groups. The impact of experience on driving behaviours of truck drivers was a key learning from the study by Fournier et al. (2007). This study in Canada found that apprentice drivers were more likely to exceed HoS limitations, often due to an inability to manage time. Albeit in truck drivers, this supports the findings of the second question of this review, in which younger age was identified as a risk factor for driver fatigue, and suggests that for a fatigue management policy to work, targeting less experienced drivers and teaching time-management skills may be useful, in conjunction with – most importantly – determining appropriate workloads for novice drivers.

Legislation relating to work health and safety and workers compensation

In Australia, driving forms an element of work for many workers, and to this end the duties and offences set out under work health and safety and workers compensation legislation are relevant. Beyond professional drivers in the heavy-vehicle and road-transport industries, work-related driving is an area of significant occupational exposure to fatigue-related risk (Boufous & Williamson, 2006).

Work health and safety law

The essence of work health and safety legislation in most jurisdictions worldwide requires that organisations must provide for a safe-system of work. Central to this is the effective identification and mitigation of risk, typically in line with international standards (International Organisation for Standardization (ISO), 2018). Specifically, the standards *ISO 45001:2018 Occupational Health and Safety Management Systems and ISO 31000:2018 Risk Management* set out the frameworks adopted in many jurisdictions worldwide to meet the duties and obligations set out in work health and safety legislation.

Within Australia, work health and safety legislation is a matter for individual states and territories, with additional commonwealth legislation covering commonwealth entities. In 2011, Safe Work Australia developed, in collaboration with Australian workplace health and safety regulators, a common set of Model WHS Acts and WHS Regulations. These have been implemented in the Australian Capital Territory, New South Wales, the Northern Territory, Queensland, South Australia, Tasmania and at a Commonwealth level. Western Australia and Victoria retained their own legislation and did not participate in harmonisation (Potter et al., 2019).

None of the Australian state and territory, nor commonwealth, workplace health and safety laws or regulations make specific mention of fatigue or fatigued driving, with the exception of commercial driving in Western Australia and mining operations in Victoria. In the case of Western Australia, where the national Heavy Vehicle Law has not been adopted, the risks associated with fatigue and commercial driving are dealt with under a workplace health and safety regulation.

Where the Australian model WHS Acts and Regulations have been adopted, the requirement to manage the risks associated with fatigued driving stem from the primary duty of care. The primary duty of care is set in s 19 of the *Work Health and Safety Act 2012* (SA)[10], as an example of the Australian model legislation.

[10] *Work Health and Safety Act 2012* (SA) s 19

(1) A person conducting a business or undertaking must ensure, so far as is reasonably practicable, the health and safety of—

(a) workers engaged, or caused to be engaged by the person; and

(b) workers whose activities in carrying out work are influenced or directed by the person, while the workers are at work in the business or undertaking.

(2) A person conducting a business or undertaking must ensure, so far as is reasonably practicable, that the health and safety of other persons is not put at risk from work carried out as part of the conduct of the business or undertaking.

(3) Without limiting subsections (1) and (2), a person conducting a business or undertaking must ensure, so far as is reasonably practicable—

(a) the provision and maintenance of a work environment without risks to health and safety; and

(b) the provision and maintenance of safe plant and structures; and

(c) the provision and maintenance of Safe Systems of work; and

(d) the safe use, handling and storage of plant, structures and substances; and

(e) the provision of adequate facilities for the welfare at work of workers in carrying out work for the business or undertaking, including ensuring access to those facilities; and

(f) the provision of any information, training, instruction or supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out as part of the conduct of the business or undertaking; and

(g) that the health of workers and the conditions at the workplace are monitored for the purpose of preventing illness or injury of workers arising from the conduct of the business or undertaking.

Within Australia, a Code of Practice sets out practical advice on how to comply with the legal duties under the work health and safety acts and regulations. A Code of Practice that is formally approved under a state or territory act then takes on special status, and is automatically admissible in a workplace health and safety prosecution. In this context, an approved Code of Practice can be relied on as evidence in terms of what an organisation should be doing to appropriately manage risks (Safe Work Australia, 2021). In most Australian jurisdictions, there are no specific Codes of Practice relating to fatigue or fatigued driving. However, the model Code of Practice relating to "*How to manage work health and safety risks*" specifically identifies fatigue as a workplace hazard that must be identified and mitigated alongside more traditional hazards such as plant and machinery or exposure to hazardous substances.

Sitting below the level of Code of Practice, are guidelines and other policy materials relating to specific workplace hazards. Fatigue is subject to such guidance and policy materials across all Australian jurisdictions, and general approaches to the mitigation of fatigue-related risk are provided. With respect to driving, these take the general form of limiting hours of work, mandating minimum rest periods, as well as providing guidance on maximum driving times and frequency of rest breaks. A summary of these levels of policy, from legislation to guidelines can be found in Table 4.

Table 4. WHS Policy Levels in Australia – Legislation/Regulation/Code of Practice/Guideline

Policy Level	Status	Similarities and Differences from Australian Legal Frameworks
WHS Legislation	Enforceable	No specific mention of fatigue or fatigued driving in any Australian WHS legislation. *General duties with respect to provision of a safe working environment.*
WHS Regulation	Enforceable	No specific mention of fatigue or fatigued driving in any Australian WHS regulation, with the exception of commercial driving in WA and mining operations in Victoria. *Detailed requirements with respect to hazard identification and risk management.*
WHS Codes of Practice	Admissable as evidence in relation to acceptable practice	No specific codes of practice relating to fatigue or fatigue and driving. *Model Code of Practice "*How to manage work health and safety risks" *specifically identifies fatigue as a workplace hazard and sets out generic processes for hazard identification and risk management.*
WHS Guidelines	Guidance only	*Various state and territory guidelines on managing workplace fatigue.*

In line with Australian legal frameworks and international standards for workplace health and safety, organisations often adopt a multi-layered approach to managing the risks of fatigue and driving (Warmerdam et al., 2017). These layers include limitations on driving time, mandatory rest breaks, appropriate journey planning and rostering, as well as the deployment of fatigue detection technologies.

With respect to workers compensation law in Australia, work-related fatigue is considered when making determinations on compensation for accidents involving commuting to and from work, even in jurisdictions where commuting might normally be excluded from considerations of compensation.

Evaluation of the effectiveness of work health and safety law

Within a risk-based approach to managing safety in the workplace context, it is often difficult to ascertain which specific forms of risk mitigation are the most effective, given most organisations put in place multiple forms of risk mitigation concurrently. Thus, it is often difficult to unpack whether the overall safety management system or specific forms of risk mitigation in isolation are associated with improvements in safety performance (Thomas, 2012). However, with respect to fatigued driving, each of the following forms of risk mitigation have been shown to help in reduce the risks associated with fatigued driving.

WHS policy and procedures: The primary mechanism used in organisations to manage work-related driving is a general framework of policy and procedure relating to driving. Typically, these frameworks stipulate principles of not working at elevated levels of fatigue-related risk, rostering and working time arrangements to afford sufficient sleep and rest and avoid extended work, as well as more specific guidance on maximum drive times and minimum rest breaks during driving. Another component of these policy frameworks is the concept of '*absolute authority to stop*' whereby a worker is formally empowered and procedurally obliged to cease driving if they deem themselves to be at elevated levels of fatigue-related risk (Higginson et al., 2019).

Hours of work: Managing hours of work (e.g. roster patterns, maximum HoS) is a key work health and safety level intervention that can be used to manage the fatigue-related risks associated with driving (Gander et al., 2011). It has been well established in the scientific literature that poor or shortened sleep, along with circadian factors, can significantly impact the cognitive domains associated with driving ability, in addition to increasing fatigue and the likelihood of a fatigue-related error while driving (including microsleeps) (Horne & Reyner, 1999). Roster schedules that include, for example, night work, early starts, long shifts, and high numbers of consecutive shifts are known to result in heightened fatigue for workers (Safe Work Australia, 2013). Additionally, ensuring that workers have sufficient time off between shifts, and that roster patterns rotate in the appropriate direction (i.e. forward-rotating), can be an effective strategy (Safe Work Australia, 2013). As such, organisational and regulatory systems that limit exposure to these potentially problematic roster features can be an effective strategy for managing fatigue-related risk for drivers.

Bio-mathematical modelling analyses: A key strategy for determining the fatigue-related risk associated with certain roster patterns is performing bio-mathematical modelling analyses (Dawson et al., 2017). Several software options can be used to perform these analyses, including FAID (InterDynamics Pty Ltd), FAST (Fatigue Science), Fatigue/Risk Index for Shiftworkers (United Kingdom Health and Safety Executive), and other commercially available options. Software options typically function in similar ways by taking into consideration prior sleep/wake opportunities and working time, and overlaying these factors with typical circadian rhythms. These models can therefore be used to determine the average likelihood of fatigue at all timepoints of a given roster. Based on this information, organisations can make operational and management decisions regarding the amount of fatigue-related risk they are willing to take on, and what mitigation strategies may be necessary (Dawson et al., 2017). Fatigue models can also be applied to the driving context, for both professional drivers, and individuals who commute to and from work shifts. This information can be used to identify critical periods where control measures can be implemented (e.g. journey management planning, carpooling, altering roster patterns, etc.).

Journey planning: In many organisations, a process of journey planning and risk assessment forms a critical component of managing the risks associated with fatigue and driving (Retzer et al., 2014). A typical journey plan requires individual drivers to consider the risks associated with time of day, driving time, road and environmental conditions, and the interaction between driving and non-driving work commitments (Warmerdam et al., 2017). Whilst fundamentally a low-level administrative control, journey plans do ensure that risks associated with fatigue and driving are at least considered by drivers and drivers are prompted to mitigate those risks.

Fatigue detection technologies: Increasingly, larger organisations are investing in fatigue detection technologies to provide an additional layer of fatigue-related risk mitigation. Several different technologies exist. Many available technologies are based on driver-facing cameras, which use facial recognition (typically eye movement sensing) to identify whether a driver is no longer looking at the road – either as a result of distraction (e.g. looking out of the window) or fatigue (i.e. having an eyes-closed microsleep). There are also classes of technology that are wearable by drivers, including brain activity monitoring (electroencephalography) headbands/hats and eyeglasses. Furthermore, technology exists that can monitor driver behaviour, including outcome variables such as lane deviation, steering corrections, etc., which can be used to indicate fatigue-related driving impairments. Aside from some technology options that use physiological measures (i.e. brain activity), most attempt to identify driver states or driver behaviours that are *indicative* of fatigue (and often also distraction) (Dawson et al., 2014). There are significant differences in validation of these technologies, and few independent studies have been performed to date on sensitivity/specificity of fatigue detection (Dawson et al., 2014). That is, how likely each device is to detect all fatigue events, and the likelihood of incorrectly classifying a non-fatigued driver as being fatigued. There are also issues of driver acceptability (i.e. whether drivers will accept an in-vehicle camera, or the requirement to wear a specific device while driving), and appropriate warning responses (i.e. what should a driver do when they receive an alert, and how does this fit in with their organisation's fatigue management policy). It must be noted that some new vehicles have fatigue monitoring software pre-installed (e.g. Mercedes Attention Assist). Similarly, some Australian jurisdictions currently use vehicle tracking cameras to monitor on road time (i.e. break duration/frequency) in certain areas. While useful from a regulatory perspective (i.e. to ensure that heavy vehicle drivers comply with work/rest requirements), work/rest timing is not necessarily reflective of driver fatigue and/or performance. Additionally, it must be noted that these technological options do not function within the 'roadside testing' paradigm.

Fatigue detection technologies provide significant new opportunities for fatigue-risk mitigation, and they are likely to be mandated in all on-road vehicles in many jurisdictions worldwide in the next decades (Higginson et al., 2019). There is an apparent appetite within industry and governmental groups to integrate fatigue detection technology into legislative and/or organisational regulations of driver fatigue (Australian Transport Council, 2011; Department of Transport and Main Roads & Queensland Government, 2018; Higginson et al., 2019). The use of this type of technology within a Safe Systems approach is considered to be a key future element of fatigue management, monitoring, and prevention in drivers (Australian Transport Council, 2011). Additionally, there are ongoing discussions within industry and regulatory groups about how to integrate fatigue detection technology within either existing fatigue management approaches (e.g. as part of an advanced fatigue management submission to the National Heavy Vehicle Regulator) or within Fatigue Risk Management Systems (FRMS) (Higginson et al., 2019). There is also the potential for fatigue detection technology to be used as a fitness for work measure - i.e. to ensure that drivers are not too fatigued to drive. However, this is not currently generally organisational practice. Furthermore, recent road safety action plans have included fatigue detection technology as a key safety feature predicted to reduce crash risk (Department of Transport and Main Roads & Queensland Government, 2018; Queensland Government, 2019). Future research must investigate driver responses to warnings to ensure user acceptability and efficacy of technological solutions.

Education and training: Driver and manager education is used by many organisations as an intervention strategy for mitigating fatigue-related risk in drivers (Gander et al., 2005). Specifically, most education and training programs develop knowledge and skills relating the human requirements for sleep, the causes of fatigue, and the consequences of fatigue while driving. Training and education modules can align with Australian Qualification Framework requirements, with a number of specific Units of Competency dealing specifically with fatigue and fatigue management.

Organisational culture: Though not an intervention per se, organisational culture around fatigue and fatigue reporting is likely to play a significant role in mitigating fatigue-related risk for drivers. Within organisations with a poor safety culture, steep authority gradients, or where drivers do not feel comfortable reporting fatigue for other reasons, fatigue is more likely to go undetected (Australian Transport Safety Bureau, 2019). For example, in a recent study on bus drivers in the UK, 78% of participants who had had a fatigue-related crash reported that their employer would not know that fatigue was the cause (Miller et al., 2020).

Health screening: Health screening of drivers (i.e. to diagnose any untreated sleep disorders that may impact fatigue-related risk while driving) has been discussed at length within the literature over the past 15 years (Donovan & Kapur, 2020). This is a potentially effective way of determining whether drivers may be at risk, with relatively straightforward treatment options in many cases. However, there is concern about the potential for drivers to lose wages and employment opportunities, and increase costs (e.g. testing, treatment, etc.) (Donovan & Kapur, 2020), in addition to screening criteria and outcomes if a sleep disorder is identified (Schiza & Bouloukaki, 2020). However, poor compliance with voluntary screening suggests that organisationally mandated sleep disorder screening may be necessary to see benefits of this strategy (Parks et al., 2009).

While each of these work health and safety interventions have demonstrated benefits with respect to reducing the risks associated with a work-related fatigue driving incident or accident, more recently, organisations have been integrating these interventions within the context of an organisational Fatigue Risk Management System (FRMS).

An FRMS adopts an integrated approach to the management of fatigue through putting in place multiple defences against fatigue-related risk. A FRMS employs components of an organisation's safety management system to enable the effective management of fatigue-related risk. As such, critical components include:

- Management Commitment
- Policy and Objectives
- Fatigue risk working group (sub-committee of WHS Committee)
- Hours of work policies for each business unit
- Fitness for duty program and tools
- Fatigue hazard reporting (already part of Safety Management Systems)
- Fatigue incident investigation (already part of Safety Management Systems)
- Employee training with respect to fatigue and health
- Health and well-being programs.

Increasingly, simply a standard roster and sufficient staff are no longer sufficient to demonstrate both short-term safety and long-term health outcomes associated with working time arrangements and fatigue are being effectively managed. A FRMS provides the structures to ensure and demonstrate an organisation is doing everything reasonably practicable to manage these risks.

Policy relating to fatigued driving – influencing investment in road safety strategy

Policy forms another element of efforts to reduce the risks associated with fatigued driving. In many respects, policy forms a critical proactive approach to complement traditional legislative and regulatory efforts to reduce the personal and financial costs associated with fatigue-related road crashes. While policy does guide legal and regulatory reform with respect to fatigued driving, in the Australian context policy also guides infrastructure investment, the content of education and awareness campaigns, and the development of future standards surrounding innovation such as fatigue-detection technologies.

This section reports the results of a scan of key policy makers in the Australian context, drawing on information provided by a range of key stakeholders, as well as a review of information in the public domain.

Government agencies

Across Australia, a significant number of government agencies have responsibility for road safety, including agencies at the commonwealth, state and territory, and local government levels. To coordinate effort, the now expired *National Road Safety Strategy (2018-2020)* was developed cooperatively by the commonwealth and state and territory governments. In support of the National Road Safety Strategy, a ten-year Road Safety Action Plan sought to ensure coordination of strategy in key road safety areas. The Strategy and Action Plan failed to meet its key road safety targets.

The expired *Road Safety Action Plan (2018-2020)* featured fatigued driving as a key strategic area for road safety action, both with respect to the heavy vehicle sector, as well as all other road users (Australian Government, 2018). Currently, a new National Road Safety Strategy is being developed, [11] and again fatigued driving features as an area of increased road safety activity, specifically from the perspective of "risky road use" and high-risk driving behaviours. The draft strategy highlights a plan to address these issues through coordinated enforcement, education, new technology and road treatments (Australian Government, 2020).

Responsibility for more detailed policy development, towards the concrete implementation of the National Road Safety Strategy lies with the Infrastructure and Transport Ministers within individual states and territories. Across each Australian state and territory multiple government agencies then play some role in policy, investment, and action with respect to addressing fatigued driving. In Victoria for example, multiple government departments and multiple government agencies contribute to the road safety effort, as highlighted in Table 5.

Table 5. Example Ministerial Portfolios and Government Agencies with responsibility for Road Safety and Fatigued driving – the Victoria Example.

Ministerial Portfolios	**Government Departments / Portfolios / Government Agencies (and responsibilities)**	
Minister for Transport Infrastructure Minister for Public Transport	VicRoads	*Road user licensing* *Road safety campaigns* *Vehicle standards and compliance*
Minister for Ports & Freight Minister for Roads	Road Safety Education Victoria	*Road user education*

[11] Noting that the time of writing, the draft National Road Safety Strategy (2021-2030) is being finalised. It is being harshly criticised by road safety advocates – see https://www.aaa.asn.au/wp-content/uploads/2021/07/210726_NRSS-submission-assessment.pdf

Minister for Road Safety and the Transport Accident Commission	Regional Roads Victoria	*Road safety infrastructure*
	Freight Victoria	*Policy development*
	Commercial Passenger Vehicles Victoria	*Road user licencing* *Operator accreditation* *Fatigue management guidelines* *Compliance and audit* *Road safety campaigns (targeted)*
	Transport Safety Victoria	*Bus operator accreditation* *Compliance and audit* *Safety investigation*
	Major Transport Infrastructure Authority	*Road safety infrastructure*
	Transport Accident Commission	*Road safety campaigns*

While detailed comparative analysis of the differences in models across the individual Australian states and territories is beyond the scope of this review, it is important to highlight the complexity of the multi-agency responsibility for elements of road safety and the need to ensure a coordinated approach is adopted in relation to fatigued driving.

Non-government organisations and industry groups

A range of non-government organisations and industry groups also play a critical role in policy development relating to fatigued driving.

Of particular relevance to the general public road user, the Australian Automobile Association and their member state and territory organisations play an important role, both lobbying for enhancements to governmental policy, strategy, standards and legislative/regulatory frameworks, and also contributing directly through their own policy and road safety activities.

The Royal Automobile Club of Queensland (RACQ) presents a typical case study of the essential role these non-government organisations play in advocating for road safety enhancement with respect to fatigued driving. From overarching policy commitment to reducing the risks associated with fatigued driving, the

RACQ has established a set of priorities for action including: 1) further research; 2) investment in infrastructure countermeasures; 3) investment in safer road design; 4) research and development relating to fatigue detection technology; as well as 5) further implementation of fatigue management programs in commercial / heavy vehicle settings.[12] Furthermore, a range of driver education resources as well as considerable investment in advertising campaigns warning drivers of the dangers associated with fatigued driving (alongside other at-risk driving behaviours – described as the "Fatal Five") contribute to the overall programs attempting to address fatigued driving within the Australian context.

Individual organisations

Individual organisations are critical in developing fatigued driving policy for their workforce, with downstream benefits for road users at large. Typically, fatigue management policies form an element of an organisation's overarching safety management system, and guide the management of fatigue-related risk across all operations, including driving.

A typical fatigue management policy within an organisational contest would generally include: 1) organisational commitment and resourcing the effective management of fatigue; 2) a fair and just commitment that enables employees to declare themselves not fit for a work-related task (such as driving) due to elevate levels of fatigue; 3) an overall governance structure and processes for the identification and management of fatigue related risk; and 4) a framework for employee education and training with respect to fatigue (Gander et al., 2011). More details relating to the implementation of these policies in terms of specific organisational forms of fatigue-risk management pertaining to occupational driving is provided in the previous section on work health and safety approaches to fatigued driving.

Lessons from legal, regulatory and policy approaches

The various legal, regulatory and policy frameworks that relate to fatigued driving in Australia can be seen as a suite of interconnected and often complementary elements of our general efforts to manage the risks associated with fatigued driving. One way of viewing the different, yet complementary elements of these approaches is in terms of reactive and pro-active approaches to the issue of fatigued driving.

This review has highlighted that criminal law and civil liability relating to fatigued driving are predominantly *reactive* in their approach. That is to say, these approaches revolve around the outcomes of fatigued driving and serve to primarily provide disincentive and punishment for instances where fatigued driving results in

[12] https://www.racq.com.au/cars-and-driving/representing-queensland-drivers/road-safety-priorities/fatigue

harm or loss. However, beyond general principles of retributive justice, the degree to which they change driver behaviour by way of general deterrent appears to be limited.

At the other end of the scale, Government and NGO policy has been shown to adopt a more *proactive* approach, by shaping the nature of and driving investment in interventions such as critical infrastructure (roadside rest areas and signage), driver education, and road safety campaigns. These reactive and proactive elements are summarised in Figure 9.

Legal, Regulatory, and Policy Frameworks

Fatigue Management Approach	Criminal Offences	Civil Liability	WHS	Passenger	Heavy Vehicle	Government and NGO Policy
Reactive	***Mostly reactive*** Relies on the objective detection of culpable driving behaviour (usually an accident resulting in serious injury or death).	***Mostly reactive*** Relies on demonstrable loss (in terms of property or injury/death), determination of negligence, and apportioning liability.	***Reactive elements*** Prosecutions for failures to manage risk or fulfil duties to provide safe system of work.	***Reactive elements*** Prosecutions for failures to manage risk or fulfil duties to provide safe system of work.	***Reactive elements*** Prosecutions for failures of compliance to prescriptive limits and associated processes.	***Limited*** Limited to identifying and targeting high risk groups.
Proactive	***Limited*** Some degree of general deterrence.	***Limited*** Some degree of general deterrence.	***Proactive elements*** General duty to identify hazard and mitigate risk. Codes of Practice.	***Proactive elements*** General duty to identify hazard and mitigate risk. Codes of Practice.	***Proactive elements*** Prescriptive limits on driving hours. Regulatory options for risk-based approach to fatigue management.	***Proactive elements*** Investment in Public Infrastructure (roadside signage and rest areas). Road Safety Campaigns. Lobbying.

Figure 9 – Summary of Fatigue Management Approaches Inherent in Legal, Regulatory and Policy Frameworks in Australia

Between criminal law and more general policy guidance, both workplace health and safety and commercial vehicle approaches to managing fatigued driving are moving towards a more proactive risk-based approach. Drawing on the general principles of hazard identification and risk mitigation, these approaches offer a range of solutions to the problem of fatigued driving from the perspective of work-related driving. Within this context, forms of risk mitigation including journey planning, education and training, fatigue detection technologies, as well as more traditional hours of work and minimum rest requirements offer organisations a range of tools to tackle fatigued driving.

The tools used by organisations to meet their duties to effectively manage fatigue as a hazard that results in work-related driving risks appear to have the most potential to be adapted for use across the broader population and outside the context of work-related driving. Whilst there will no doubt be limitations in terms of enforceability and compliance in the general public, the innovative approaches to fatigue risk management afforded through such things as fatigue detection technologies are examples of a more proactive approach to fatigue risk management that have the potential to inform policy for fatigued driving and the general road user.

Key countermeasures in managing fatigued driving

Roadside policing

Even if Australia's road safety legal frameworks made driving whilst fatigued more explicitly an offence, the lack of suitable roadside testing for fatigue effectively rules out enforcement as a viable option in the short term. Unlike roadside testing for alcohol and other drugs, it is not possible to ascertain that a driver is fatigued during a routine traffic stop. Even in the case of a crash, it can be difficult to definitively determine if fatigue was a contributory factor.

Whilst it has been suggested that tests used in the laboratory to measure fatigue, such as reaction-time and vigilance tasks might be able to be adapted for the context of roadside testing (Baulk et al., 2008), no jurisdictions have gone down this path in practice to date. Currently, Australian researchers are attempting to find a fatigue bio-marker that could be used in a similar way to roadside breath testing (Chang et al., 2019; Grant et al., 2019; Mullington et al., 2016). However, this research is ongoing.

There is also the potential for fatigue detection technology to play a role in roadside policing. Issues surrounding the potential use of the different forms of fatigue detection technologies is provided a following section.

Behavioural countermeasures

Caffeine: Caffeine is the most investigated behavioural countermeasure for fatigue. In multiple studies under laboratory conditions, caffeine ingestion (ranging from 80mg – the equivalent to one cup of black tea - to 250mg – the equivalent of approximately 1 – 1.5 cups of espresso coffee) has been shown to be effective in reducing driver fatigue (Aidman et al., 2018; De Valck & Cluydts, 2001; Gesteldi et al., 2016; Mets et al., 2012; Mets et al., 2011; Reyner & Horne, 2000; Reyner & Horne, 2002; Wijayanto et al., 2018). Within these studies, driver fatigue is indicated by driver performance (e.g. driving errors, vehicle positioning, weaving, speeding) in addition to self-reported sleepiness. These studies found evidence to support the use of coffee to improve driving performance when fatigue is caused by sleep deprivation (Aidman et al., 2018; De Valck & Cluydts, 2001; Reyner & Horne, 2000; Wijayanto et al., 2018) and fatigue caused by an extended period of driving (Gesteldi et al., 2016). Similar results have been found for caffeine ingested as an energy drink, with improved driving performance after an energy drink found after sleep restriction (Reyner & Horne, 2002) and after an extended drive time (four hours) (Mets et al., 2011). As with the laboratory findings, caffeine was also identified as an effective intervention from an observational study by Pešić et al. (2015) conducted in Serbia. Drivers in these studies perceived caffeine as reducing fatigue and improving driving performance, suggesting an awareness of the benefits of this intervention.

Together, these studies provide robust evidence for the use of caffeine as an effective behavioural intervention for driver fatigue. Given that caffeine is readily available and cost-effective, it could be an effective countermeasure option to emphasise for drivers. Caffeine was also shown to be effective in studies that compared the efficacy of multiple countermeasures, for example combining caffeine and napping as a countermeasure appears to be beneficial for fatigued driving (Sagaspe et al., 2007). However, there are concerns associated with caffeine use, such as developing a tolerance (Centofanti et al., 2018) or increasing gastrointestinal upset (Gunja & Brown, 2012). Additionally, a study compared driver outcomes in groups with high (five or more caffeinated beverages per day) and low (one caffeinated beverage consumed per day) caffeine use, and showed no improvements in driver safety outcomes. The findings suggest that tolerance occurs, and that caffeine is not a sufficient countermeasure in situations where very poor sleep, problematic rosters, or other factors are in play (Filtness et al., 2020). However, it appears that generally, caffeine can be a useful behavioural countermeasure to fatigue when used appropriately.

Napping: Napping is considered a potential prophylactic behavioural intervention to improve alertness. However, laboratory studies have produced mixed results regarding the effects of naps on driving performance. Horne and Reyner (1996) found that the number of incidents (e.g. lane deviations) was significantly reduced following a nap condition, as compared with a placebo. In 1997, these authors also found that the mid-afternoon peak in driving incidents was eliminated by a combination of caffeine and a ~15 minute nap – a significantly better outcome than caffeine alone or a placebo (Reyner & Horne, 1997). Similarly, in a highway driving study, fewer inappropriate line crossings were seen in a 30-minute nap condition as compared with a placebo condition (Sagaspe et al., 2007). These findings are supported by other similar naturalistic (Philip et al., 2006) and simulator studies (De Valck et al., 2003) demonstrating improved driving performance following a 30 minute nap.

Conversely, several studies do not support napping as an effective countermeasure. In a study by Lenné et al. (2004), eight adult drivers had a 60-minute nap in quiet or noisy conditions, with no significant improvements in simulated driving performance after either nap opportunity. The protocol involved a high level of fatigue, combined with a long nap duration and short drive assessment, and therefore may not reflect optimum napping conditions. A shorter nap opportunity was provided by Hilditch et al. (2017), in which 21 drivers had a 10-minute nap opportunity before a simulated drive. The nap opportunity did not lead to significantly improved driving performance – though this nap was of shorter duration than is typically recommended within driver safety campaigns (~20 minutes). Armstrong et al. (2010) included stopping the drive and sleeping prior to recommencing the drive in a list of 18 fatigue interventions that drivers could evaluate. In this study, participants believed that stopping and sleeping was the most effective intervention, even though the intervention of stopping to sleep might be considered more than a short nap. However, despite several studies suggesting that under certain conditions, naps may not be an effective behavioural countermeasure, the duration of nap typically recommended by road safety campaigns (~20 – 30 minutes) is supported by the current literature.

General health and stress management: It is well established that poor health and stress are associated with both poor sleep and greater fatigue (Åkerstedt et al., 2014; Kim & Dimsdale, 2007). These factors are also associated with poor driving outcomes (Taylor & Dorn, 2006). For example, stressful working conditions are associated with riskier driving behaviour in a bus driver population, with analyses indicating that fatigue plays a mediating role in this relationship (Useche et al., 2017). Similarly, research indicates that stress is associated with poorer sleep outcomes (Dahlgren et al., 2005), which is then likely to impact driver fatigue. As such, reducing personal stress may be an effective strategy in mitigating the fatigue-related driving risk, though to the authors' knowledge no research has been performed specifically addressing this as a countermeasure.

Ineffective countermeasures: Additional behavioural interventions that were shown to be ineffective (or having only minimal effectiveness) include engaging in a conversation (Large et al., 2018), turning the air conditioner on (Schmidt & Bullinger, 2019), and listening to music (Hasegawa & Oguri, 2006). Importantly, each of these potential countermeasures have limited and inconsistent efficacy (Reyner & Horne, 1998; Schwarz et al., 2012). In fact, common countermeasures such as opening a window and listening to music have been characterised as 'popular, but hardly effective' (Schwarz et al., 2012).

The scientific literature has demonstrated that behavioural countermeasures used by individual drivers are effective mitigators of fatigue-related risk. In particular, the literature highlights caffeine and napping as effective countermeasures, both of which are well-known and common features of road safety campaigns.

Infrastructure interventions

Rest breaks and rest areas: The use of rest breaks and rest areas as a behavioural intervention was explored in observational studies identified from this review. A reduction in fatigue-related crashes was seen when the number of rest breaks increased in a sample of truck drivers in the USA (Chen & Xie, 2014). Additionally, a reduction in crashes due to drowsy driving (identified through police reports) was seen after additional rest areas along freeways/motorways were created (Jung et al., 2017; Reyner et al., 2010). A rest break was explored as a possible intervention in one laboratory-based study (Phipps-Nelson et al., 2011). The study, conducted in Australia, involved a two-hour drive on a simulator with a one-hour break after the first hour. Driving performance and fatigue ratings improved following the scheduled break from driving. This study supports the use of road safety campaigns that describe scheduling breaks every two hours. Together, findings from observational and experimental studies endorse the use of rest breaks and rest areas for reducing fatigue related driving impairment. However, future research should investigate the ideal duration for mid-drive breaks (i.e., how long to stop for during a drive to optimally manage fatigue). In addition, it is important to understand which factors associated with rest breaks and rest areas reduce fatigue. That is, it may be a combination of the break, with the opportunity to consume caffeine, engage in exercise, etc., that may reduce post-break driver fatigue.

The importance of rest areas is also discussed with Australian road safety plans, including auditing of current rest areas, and the development of a smartphone application designed to identify local rest areas (Department of Transport and Main Roads & Queensland Government, 2018). This has been described by the Queensland Government as being successful in managing heavy vehicle driver fatigue, but several subsequent interventions have been proposed. These proposed strategies include the integration of data sources with the rest area application, including the potential for real time rest area availability information, and the construction of additional heavy vehicle stopping areas (Department of Transport and Main Roads & Queensland Government, 2018; Queensland Government, 2019).

Road features: Infrastructure-based interventions, such as rumble strips, chevrons, and message signs, have been assessed in several experimental studies (Anund et al., 2011; Anund et al., 2008; Merat & Jamson, 2013; Watling et al., 2016). In the study by Merat and Jamson (2013), driving performance on a simulator improved after the addition of chevrons, rumble strips, and message signs, compared to control conditions without these interventions. Rumble strips were similarly shown to be effective in the study by Watling et al. (2016), with physiological sleepiness significantly reduced after the first rumble strip hit. However, in this study, subsequent rumble strip hits did not impact alertness, suggesting that perhaps this infrastructure intervention has acute effectiveness, but for longer drives additional interventions may be needed. However, there is also evidence to suggest that while rumble strips can have an immediate alerting effect, these effects do not impact fatigue over longer periods (e.g. > 5 minutes) (Anund et al., 2008). As part of the now expired National Road Safety Strategy 2011 – 2020, features such as wire rope barriers are recommended to reduce the likelihood of head on crashes due to fatigue or inattention (Australian Government, 2010). In addition separation of opposing traffic via wider medians is suggested as a potential risk mitigation feature (Australian Government, 2010). In the *Queensland Heavy Vehicle Safety Action Plan 2019 – 2020*, road features such as wide centreline treatments and audio tactile line markings (i.e. rumble strips) have also been identified as successful solutions – though no data is provided to underpin these claims (Department of Transport and Main Roads & Queensland Government, 2018). An Australian study on the efficacy of roadside signage (both highlighting the dangers of fatigue and presenting a set of trivia questions designed to keep drivers alert) on fatigue and alertness outcomes found that when signs were used, participants reported increased alertness (Roberts et al., 2011). However, roadside signage did not appear to impact the decision to stop driving (though it must be noted that these signs did not specifically direct drivers to stop), and a comparison study of different sign types has not been performed.

The systems approach to road safety highlights that safety is a product of more than the driver, the vehicle and the road conditions in isolation. The overarching design of a road traffic 'system' in a way that acknowledges the complexity of interactions between the many and varied components of the system is critical in achieving enhanced safety outcomes. To this end, infrastructure interventions, from the provision of rest areas through to features such as rumble strips and roadside signage play an important part in addressing the risks associated with fatigue and driving, and represent an area for future research and development.

Advertising campaigns, education and attitudinal change

While numerous studies have discussed fatigued driving advertising campaigns, only two studies were identified investigating the effectiveness of these campaigns. This supports findings of a review conducted by Jackson et al. (2011), suggesting that this gap in the literature has been prevalent for some time.

The European fatigued driving campaign (2008 – 2009) investigated in the study by Adamos et al. (2013) was effective at increasing knowledge of fatigue related crashes and countermeasures among drivers, and reduced the frequency (self-reported) of participants' driving while fatigued. This campaign included the slogans "eyes on the road" and "sleep but not at the wheel", and included television and radio advertisements, leaflets, posters, newspaper inserts, electronic billboards, online advertisements, and messages printed on the reverse side of public transportation tickets. Further evidence for the effectiveness of fatigued driving advertising campaigns was found in an Australian study by Tay and Watson (2002), who investigated the effectiveness of a fatigued driving campaign with a high stress stimuli of a violent car crash, compared to a low-stress campaign with coping strategies for driver fatigue. The coping strategies included in the campaign were pulling over and taking a short nap, stopping for a coffee break, and swapping drivers. Results indicated that the campaign with coping strategies was more effective in leading to behaviour change, with participants more likely to report intentions to take positive action to reduce fatigue.

Despite a review conducted ten years ago calling for a greater number of 'before' and 'after' measurements to assess the efficacy of safe driving campaigns (Wundersitz et al., 2010), they are still lacking in the literature, particularly for fatigued driving. However even with more research into the efficacy of fatigue risk driving campaigns, assessing how effective the campaign has been for an entire driving population would be challenging.

While only two studies were identified through the literature search, these studies suggest some effectiveness of fatigued driving advertisement campaigns, particularly when countermeasures are suggested rather than the use of violent crash imagery. However, more research in this area is warranted, as the long-term effectiveness of such campaigns at reducing fatigue-related crashes has not been investigated. Future campaigns could specifically target the high-risk groups identified earlier in the review.

An additional intervention at the organisational level is driver education programs. Such programs were investigated in several key observational studies (Alvaro et al., 2018; Pylkkönen et al., 2018). In the study by Alvaro et al. (2018), Australian drivers completed a four-week education program about sleep and driving, with those that received the education program more likely to indicate that they would stop driving if they were fatigued. However, the driving outcomes did not differ between groups, suggesting minimal effectiveness of the intervention for fatigued driving outcomes. Education programs were also investigated in the study by (Pylkkönen et al., 2018), in which 53 truck drivers in Finland received 3.5 hours of alertness management training followed by a two-month consultation period during which participants could contact trainers via email or phone for any questions or inquiries. This program did not lead to significant improvements in driver sleepiness or use of sleepiness countermeasures while driving during the night and early morning shifts, compared to day or evening shifts. Conversely, a graduated driver-licensing program in Massachusetts that included a drowsy driving component, and prohibited driving at night was implemented in 2007 (Rajaratnam et al., 2015). Pre- and post- comparisons were performed, which indicated an 18.6% decrease in the crash rate for young drivers, in addition to a decrease in incident rate ratios for young drivers by 39.8% for fatal or incapacitating injury, and 28.8% for crashes at night. As such, driver education that includes specific fatigue management strategies (Tay & Watson, 2002), and legislative programs that include both education and the prohibition of driving at times when fatigue likelihood is high (i.e., overnight) (Rajaratnam et al., 2015) may be effective. The impact of such programs is important to understand, given that graduated driver licensing programs are currently in place in Australia. Some of these programs include the restriction of night driving (e.g., provisional drivers may not drive between midnight and 05:00 hrs in South Australia), in an effort to reduce fatigue-related risk. However, further research is necessary to identify which training components are effective and how to best implement these programs.

Behavioural programs and driver education have been discussed at length by governmental and road safety organisations. However, no consistent evidence is available as to their effectiveness in reducing either fatigued driving or rates of fatigue-related vehicle crashes. Thus far, priority has been given to interventions that provide driver education regarding fatigue (and other driver behaviour) (Australian Transport Council, 2011). Historically, these driver educational campaigns have included messaging such as 'wake up to the signs of fatigue', in addition to providing simple heuristics for breaks ('take a 15-minute break every two hours') and for identifying fatigue ('sore or heavy eyes', 'general tiredness', etc.) (Department of Transport and Main Roads, 2009). Additionally, heath initiatives for heavy vehicle drivers have included fatigue as a key factor – though no data are available regarding efficacy (Department of Transport and Main Roads & Queensland Government, 2018). Future research should be performed on current Australian fatigue-related road safety campaigns to understand what strategies are most effective in the Australian context.

As a traditional component of the overarching road safety agenda, advertising and education campaigns have been shown to be somewhat effective and will continue to form an important element of managing the risks of fatigue and driving. However, inconsistencies in the scientific evidence to support these programs suggests the need for further detailed evaluation.

It is critical to be aware of the appropriate countermeasures that could or should be used in response to certain situations. For example, behavioural countermeasures such as caffeine are unlikely to be sufficient to mitigate fatigue-related risk in circumstances where sleep is severely restricted. Likewise, infrastructure interventions such as roadside rest areas may not be sufficient in cases where organisational culture does not promote taking breaks while driving. As such, care must be taken to identify appropriate countermeasures given the driving circumstances. However, as noted above, sleep is the only countermeasure that is definitely effective – we cannot definitively state that certain other behavioural countermeasures will prevent fatigue-related vehicle crashes.

Summary and Future Priorities

This review has highlighted that fatigued driving remains a very real area for concern with respect to road safety across all road user groups. Estimates of prevalence from the literature suggest that fatigue contributes to somewhere between 2% and 16% of road crashes in Australia. Additionally, fatigue has consistently remained as one of the top five road safety priorities in Australia, alongside seatbelt use, speeding, drug and alcohol impairment, and distraction - often referred to as the 'fatal five'.

The review has also highlighted a range of limitations inherent in our current efforts to curb the contribution of fatigue to road crashes in Australia. These limitations include:

- A generally reactive approach to fatigue with respect to criminal and road safety law, whereby driving whilst impaired by fatigue is not construed as an offence in and of itself, until such impairment results in a serious road crash;
- Fatigue is not considered an inappropriate "at-risk" driving behaviour in the same way as speeding or drink-driving by the general population;
- The lack of mechanisms to detect fatigued driving, and therefore limitations with respect to enforceability should driving whilst fatigued become an offence in and of itself, as is the case with speeding and drink-driving;
- A lack of detailed understanding of how to appropriately target behavioural interventions, such as advertising campaigns, to reduce the prevalence of fatigued driving; and
- Limited availability of scientifically validated low-cost fatigue detection technologies for the general road-user population, and appropriate recognition of these devises in vehicle safety standards.

A set of future priorities for addressing the issues associated with fatigued driving are evident.

Fatigue detection technologies

The review has highlighted that as an effective countermeasure against the catastrophic impacts of fatigue and driving, fatigue detection technologies provide an important form of risk mitigation that is currently gaining in momentum in commercial, professional and road-transport sectors.

The ability to detect when a driver is impaired, either through exhibiting behaviours consistent with a state of drowsiness or through the detection of high-risk driving behaviours such as lane-drifting is an important recent scientific innovation. Fatigue detection systems in general appear to provide valid and reliable tools for fatigue-risk mitigation. Future research with respect to the evaluation of such systems and how they are integrated into an overall systematic approach to managing the risks of fatigue and driving is warranted.

Driver decision-making and stopping driving when fatigued

This review has highlighted that the decision to continue to drive, even when aware of symptoms of fatigue, is the main priority for future research and action in relation to driver behaviour. In the occupational setting, policies and procedures around an 'absolute authority to stop driving', when supported by an appropriate organisational culture, and the necessary road-side infrastructure, provides drivers with support in their decision-making around stopping driving when fatigued.

However, in both the occupational setting and for the general road user, pressures relating to the perceived financial and time costs associated with the decision to cease driving are often perceived to outweigh the perceived risks associated with a fatigue-related crash.

The current science does not provide a sufficiently detailed understanding of driver decision-making in this regard. The research clearly demonstrates that drivers are aware of increasing fatigue levels, and the precursor symptoms of falling asleep. However, we still do not know enough about the underlying decision-making process that leads drivers to continue driving to target appropriate interventions that will lead to behavioural change. Some research exists in the area of speeding and behaviour change suggesting that external motivating factors are perceived as more important than safety (Adams-Guppy & Guppy, 1995), and this may also apply to fatigue. Speeding has been conceptualised under the theory of planned behaviour, which describes behaviours as occurring as a result of intentions (i.e. planned behaviour), which in turn are produced by attitudes, beliefs, norms, and perceived behavioural control (Newnam et al., 2004). This type of behavioural theory may also be applicable to fatigue and driving – though there has been no investigation in this area to date that this literature review has identified. Similarly, research has been performed into the concept of 'goal seduction' in the areas of emergency management (Bearman & Bremner, 2016) and aviation (Bearman et al., 2009). In this context, goal seduction refers to the performance of behaviours that are unsafe as a result of the desire to complete a goal (Bearman et al., 2009). While goal seduction has not been investigated in the context of driving (either professional or non-professional), future research may produce strategies that encourage drivers to stop driving when fatigued (to stop short of their driving 'goal' if they feel fatigued). As such, the behavioural motivations for driving while fatigued is another clear priority for future research and development.

Preparatory behaviours

A clear future priority for Australian road safety includes a focus on behavioural countermeasures that can be used by drivers to reduce fatigue-related driving risk. There is evidence supporting the use of certain countermeasures, for example napping and caffeine, which have been used consistently in Australian and international road safety campaigns. However, little consideration has been given to preparatory behaviours that could be performed prior to driving to mitigate fatigue-related risk. It is well known that having sufficient sleep prior to driving is a key factor in reducing fatigue-related crash risk. This is a relatively straightforward message that could be included in road safety advertising campaigns in future. Similarly, the promotion of pre-drive planning (particularly long drives) could be effectively communicated to drivers to reduce this risk. For example, drivers could be encouraged to plan long drives at appropriate times of day (e.g. avoiding the early hours of the morning), ensuring that they have had sufficient sleep the night before. Additionally, rest stops and other mitigation strategies could be included in pre-drive planning.

Potential for legal reform – towards enforceability and proactive approaches to fatigue management

This review has highlighted a potential future need for additional legal frameworks with respect to managing the risks of fatigue and driving. Current legal frameworks for managing fatigue in Australia for the general driving population rely almost entirely on the prosecution of drivers for offences relating to dangerous driving - after a crash has occurred. This review has highlighted that the threat of prosecution should a crash occur because of driving whilst fatigued probably provides little disincentive for the general population. The legal and regulatory frameworks adopted in the heavy vehicle industry highlight the role of a greater risk-based approach that takes into consideration factors such as the likelihood of fatigue, through regulating driving hours, and mechanisms to mitigate the risks of fatigue such as enforceable rest periods and the use of innovative solutions such as fatigue detection technologies.

In the USA, 'Maggie's Law' provides one viable alternative approach to managing the risks of fatigue and driving from a legal perspective, by establishing *prima facie* impairment and culpability if a driver has been awake for 24 hours at the time of the crash. Whilst this approach simplifies the decision-making with respect to whether fatigue was a contributory factor in a crash, it probably does not go far enough towards effective legislative disincentive to drive whilst fatigued. It is also limited by virtue of defining fatigue only in terms of excessive wakefulness, and only creating a criminal offence when an accident results in a fatality.

In most jurisdictions worldwide, road safety laws set a prescribed limit of blood alcohol concentration, above which you are 'deemed to be impaired'. That is, driving performance is not used to determine whether an offence has been committed – rather, blood alcohol concentration is used as a proxy. Given appropriate legislative frameworks, driving whilst deemed impaired (from alcohol or drugs) is an offence in and of itself, regardless of whether that driving was in a dangerous manner or whether a crash occurred. It is increasingly possible to translate this approach to the risks associated with fatigue. First, through the measurement of sleep wake behaviours (using technologies such as wearables), and secondly through emergent research establishing valid and reliable assays for roadside fatigue detection through performance test, or other means (Grant et al., 2019).

The science relating to the relationship between sleep, wake, and performance impairment is now at a level of sophistication that we should be able to set threshold levels of an individual's prior sleep wake history that would be consistent with the types of performance impairment we see at prescribed blood alcohol concentrations (Dawson et al., 2020). This is evidenced by the strong relationships seen in the literature between prior sleep wake behaviour and subsequent performance impairment (Belenky et al., 2003; Van Dongen et al., 2003). Within this literature, significant decrements to performance can be seen when there has been fewer than five hours of sleep obtained in the previous 24 hours – performance decrements similar to those seen at a blood alcohol concentration of > 0.05% (Dawson & Reid, 1997). Further, there has been an explosion in the use of wearables that record sleep wake patterns – several which have been validated against 'gold standard' measures of sleep assessment (de Zambotti et al., 2018; Liang & Nishimura, 2017; Svensson et al., 2019). Data from these devices are already discoverable at law, providing a sound basis for exploring the concept of deemed impaired from a fatigue perspective in future law reforms (Dawson et al., 2020).

The concept of 'deemed impaired' is one which has significant merit and potential for future law reform with respect to fatigue and driving (Dawson et al., 2020). The concept of 'deemed impaired' states that a driver is not in a state fit to drive if they have not had sufficient sleep or have been awake for excessive periods. The concept is similar to that of drug and alcohol impairment and the manner in which it is dealt with under road safety law. In most jurisdictions worldwide, road safety law sets a prescribed limit of blood alcohol concentration, above which you are 'deemed impaired'. Given appropriate legislative frameworks, driving whilst deemed impaired is an offence in and of itself, regardless of whether that driving was in a dangerous manner or whether a crash occurred.

Infrastructure interventions and a "fatigue proof" Safe Systems approach.

Infrastructure interventions, as part of a Safe Systems approach, have been shown to be highly effective in mitigating certain aspects of fatigue-related risk for drivers. As such, the promotion and funding of these interventions could be an additional management strategy. For example, increased availability of rest stops in areas where fatigue may be a risk (e.g. rural areas), in addition to the use of controls such as rumble strips and road widening may be effective.

Of particular interest for future developments is the Safe System approach to road safety, as applied to the risks associated with fatigued driving. The Safe System approach, which has been adopted in various jurisdictions worldwide holds that human error is a ubiquitous and fundamental element of the human condition, and that it must be anticipated and accommodated for within the road transport system (Job et al., 2017). To this end, the road transport system must be designed to anticipate and tolerate fatigued drivers. This would generally include fatigue management to be considered by the during planning, design, operation, and use of a road network (Transport Research Centre et al., 2008).

The Safe Systems approach is captured in the concept of 'Fatigue Proofing' a system, where systems are designed to be error tolerant, and the impairment associated with fatigue is prevented from causing harm (Dawson et al., 2012). Currently, road infrastructure interventions, such as rumble strips in place to alert drivers to lane deviations meet the criteria for creating a "fatigue proof" Safe System of road transport. However, a more consolidated and integrated approach is needed to truly create a Safe System for fatigued driving. Given the nature of Australia's road network, road and roadside infrastructure interventions might not be a feasible central component, and in-vehicle technological advancements might be the more appropriate option.

In short, a Safe Systems approach demands some reorientation of our efforts in tacking the problems associated with fatigued driving, away from a focus on prevention, to include a greater emphasis on designing systems that prevent harm from ubiquitous Human Factors issues such as fatigue.

Fatigue Risk Management Systems (FRMS)

In other industries such as commercial aviation, the creation of Fatigue Risk Management Systems (FRMS) has become the 'gold-standard' for managing occupational risks associated with fatigue. While the complex road transport system presents challenges for adopting an approach typically deployed within the context of a single organisation, the overarching principles of an FRMS could be used as a framework to assist better coordination of efforts in a systematic manner between the various stakeholder groups currently involved in efforts to combat fatigued driving.

A FRMS can be defined as the application of the principles of Safety Management Systems, to the management of fatigue-related risk. To this end, rather than just relying on compliance with prescriptive work and rest rule-sets to manage the safety-related risks of fatigue, a FRMS employs multiple strategies to manage fatigue, such that each strategy forms an additional layer of defence against fatigue.

While a FRMS approach has matured to be recognised as "best-practice" fatigue management in many occupational settings, the FRMS approach can also provide guidance as to a better integrated, and more comprehensive, approach to identifying and managing the risks associated with fatigue and driving for the general public. Adopting a FRMS framework might enhance the integration of activities from the wide-range of current stakeholders in road safety, from automobile associations, road safety commissions and other government agencies, not for profit organisations, state and territory police.

In summary, better integration and coordination of efforts from key-stakeholders, and a more systematic approach to delineation of responsibility for specific strategies to combat fatigued driving might be able to be achieved through drawing lessons from the FRMS approach. Similarly, the FRMS approach supports a considered risk-based orientation for these efforts, with an increasing emphasis placed on pro-active strategies that embed a Safe Systems approach to what has been a truly stubborn issue facing road safety in Australia.

Key Researchers and Groups

As evident in the reference list of this review, a large number of outstanding researchers and research groups have contributed to the considerable body of scientific knowledge relating to fatigue and driving.

In many respects, it would be inappropriate to single out individual researchers at the expense of others in creating a table of key researchers. Accordingly, Table 6 provides a list of key research organisations in the area of driver fatigue and road safety. The current Directors of these research groups are identified to provide a point of contact.

Table 6. Key research groups in the area of driver fatigue and road safety

Director	**Research Group**	**Country**	**Relevant Expertise**
Prof Sally Ferguson Director, Appleton Institute	Appleton Institute for Behavioural Science, CQUniversity	Australia	Human factors; sleep physiology; fatigue risk management systems; fatigue models; laboratory-, simulator- and field-based protocols
Mr David McTiernan National Leader, Transport Safety, AARB	Australian Road Research Board (AARB)	Australia	Policy and strategy development; road design and traffic engineering; road user behaviour and education; crash investigation; heavy vehicles
Prof Andry Rakotonirainy Director, CARRS-Q	Centre for Accident Research and Road Safety – Queensland (CARRS-Q), Queensland University of Technology	Australia	Driving simulation; augmented reality; driver assist vehicles; automated vehicles
A/Prof Jeremy Woolley Director, CASR	Centre for Automotive Safety Research (CASR), The University of Adelaide	Australia	Safe road users; safe infrastructure; safe vehicles; road crash investigation

A/Prof Mark Howard Director, Victorian Respiratory Support Service	Institute for Breathing and Sleep (IBAS), Austin Health	Australia	Impact of sleep disorders on driver safety
Prof Judith Charlton, Director, MUARC	Monash University Accident Research Centre (MUARC), Monash University	Australia	Safety science; systems safety; crash investigation; traffic engineering
A/Prof Soufiane Boufous Acting Director, TARS	Transport and Road Safety (TARS), University of New South Wales	Australia	Safety systems; human factors; crashworthiness; information technology
Prof Shantha Rajaratnam Director of Industry Engagement and Translation, Turner Institute	Turner Institute for Brain and Mental Health, Monash University	Australia	Fatigue detection technologies; biomarkers of fatigue; drowsy driving
Professor Jeremy Davey Leader	USC Road Safety Research Collaboration, University of the Sunshine Coast	Australia	Impaired driving, enforcement, policy development.
Prof Lynn Meuleners Director, WACRSR	Western Australia Centre for Road Safety Research (WACRSR), University of Western Australia	Australia	Human factors; driving simulation; fatigue and distraction; countermeasures; evidence-based policy
Prof Mikael Sallinen Head of Program, FIOH	Finnish Institute of Occupational Health (FIOH)	Finland	Sleepiness countermeasures; fatigue management; heavy vehicles
Prof Pierre Philip Director	GENPPHAASS (Study group of neurophysiology, pharmacology, sleep and sleepiness), University of Bordeaux	France	Sleep disorders, sleepiness, road safety.

Prof Anna Anund Research Director, VTI	Swedish National Road and Transport Research Institute (VTI)	Sweden	Human-machine interaction; highway engineering; driving simulation
Prof Andrew Morris Director, TSRC	Transport Safety Research Centre (TSRC), Loughborough University	UK	Accident investigation; road user behaviour; human factors; driving simulation; crashworthiness
Prof Hans Van Dongen Director, SPRC	Sleep and Performance Research Center (SPRC), Washington State University	USA	Heavy vehicles; fatigue risk management systems; fatigue models; sleep loss; laboratory protocols
Dr James Sayer Director, UMTRI	University of Michigan Transportation Research Institute (UMTRI), University of Michigan	USA	Distraction; workload; advanced driving systems; protocols using simulators, test track and on-road

Appendix A – Search Terms

Topic 1

Estimates from the international body of research about the number of fatigue-related crashes in Australia and internationally

Search Terms (search conducted 26th March 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automectivile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (crash* OR accident* OR collision* OR incident* OR injur* OR fatal* OR death* OR trauma) AND (rate* OR likelihood OR incidence OR prevalence OR occurrence OR number OR risk)
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 505**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (crash* OR accident* OR collision* OR incident* OR injur* OR fatal* OR death* OR trauma) AND (rate* OR likelihood OR incidence OR prevalence OR occurrence OR number OR risk))2000-2020, peer-reviewed, English
- **Total papers = 201**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("Abstract":crash OR "All Metadata":accident OR "All Metadata":collision OR "All Metadata":incident OR "All Metadata":injur* OR "All Metadata":fatal* OR "All Metadata":death OR "All Metadata":trauma) AND ("Abstract":rate OR "All Metadata":likelihood OR "All Metadata":incidence OR "All Metadata":prevalence OR "All Metadata":occurrence OR "All Metadata":number OR "All Metadata":risk))
- Year: 2000-2020, journal articles
- **Total papers = 63**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (crash* OR accident* OR collision* OR incident* OR injur* OR fatal* OR death* OR trauma) AND TITLE-ABS-KEY (rate* OR likelihood OR incidence OR prevalence OR occurrence OR number OR risk) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 1236**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (TS=(crash* OR accident* OR collision* OR incident* OR injur* OR fatal* OR death* OR trauma)) AND (TS=(rate* OR likelihood OR incidence OR prevalence OR occurrence OR number OR risk))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 1228**

Topic 2

Assessment from the international body of literature about whether, and why, there are at-risk groups for fatigued driving (e.g., young drivers, shiftworkers)

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (at-risk OR "at risk")
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 446**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (at-risk OR "at risk"))2000-2020, peer-reviewed, English
- **Total papers = 18**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata":at-risk OR "All Metadata":"at risk"))
- Year: 2000-2020, journal articles
- **Total papers = 95**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY ("at risk" OR at-risk) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 75**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (TS=(at-risk OR "at risk"))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 57**

Topic 3

Assessment from the international body of literature regarding the effectiveness of interventions (including but not limited to technology-based interventions, behavioural-based interventions, and infrastructure-based interventions) to manage fatigued driving

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (intervention* OR technolog* OR behav* OR infrastructure OR counter* OR strateg* OR manage*) AND (effect* OR affect*)
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 580**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (intervention* OR technolog* OR behav* OR infrastructure OR counter* OR strateg* OR manage*) AND (effect* OR affect*))2000-2020, peer-reviewed, English
- **Total papers = 173**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata": intervention* OR "All Metadata":technolog* OR "All Metadata":behav* OR "All Metadata":infrastructure OR "All Metadata":counter* OR "All Metadata":strateg* OR "All Metadata":manage*) AND ("All Metadata":effect OR “All Metadata”:affect))
- Year: 2000-2020, journal articles
- **Total papers = 211**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (effect* OR affect*) AND TITLE-ABS-KEY (intervention* OR technolog* OR behav* OR infrastructure OR counter* OR strateg* OR manage*) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 837**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (TS=(intervention* OR technolog* OR behav* OR infrastructure OR counter* OR strateg* OR manage*)) AND (TS=(effect* OR affect*))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 898**

Topic 4

Assessment from the international body of literature regarding the effectiveness of fatigue management policy and arrangements for different workforces

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR "code of pract*" OR "codes of pract*" OR manage*) AND (effect* OR affect*)
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 192**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR "code of pract*" OR "codes of pract*" OR manage*) AND (effect* OR affect*))2000-2020, peer-reviewed, English
- **Total papers = 37**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata":polic* OR "All Metadata":arrangement* OR "All Metadata":law* OR "All Metadata":regulation* OR "All Metadata":legislation OR "All Metadata":guid* OR "All Metadata":code of practice OR "All Metadata":manage*) AND ("All Metadata":effect OR "All Metadata":affect))
- Year: 2000-2020, journal articles
- **Total papers = 60**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (effect* OR affect*) AND TITLE-ABS-KEY (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR "code of pract*" OR "codes of pract*" OR manage*) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 347**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (TS=(polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR "code of pract*" OR "codes of pract*" OR manage*) AND (TS=(effect* OR affect*))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 344**

Topic 5

Assessment from the international body of literature regarding the effectiveness of fatigued driving advertising campaigns (noting that not all advertising is based on evidence / research)

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (advertis* OR campaign OR communication OR television OR "safety advertising" OR "fatigue campaign" OR "road safety campaign")
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 60**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (advertis* OR campaign OR communication OR television OR "safety advertising" OR "fatigue campaign" OR "road safety campaign"))2000-2020, peer-reviewed, English
- **Total papers = 53**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata":advertis* OR "All Metadata":campaign OR "All Metadata":communication OR "All Metadata":television OR "All Metadata": "safety advertising" OR "All Metadata": "fatigue campaign" OR "All Metadata": "road safety campaign"))
- Year: 2000-2020, journal articles
- **Total papers = 656**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (effect* OR affect*) AND TITLE-ABS-KEY (advertis* OR campaign OR communication OR television OR “safety advertising” OR “fatigue campaign” OR “road safety campaign”) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 205**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (TS=(advertis* OR campaign OR communication OR television OR “safety advertising” OR “fatigue campaign” OR “road safety campaign”))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 188**

Topic 6

Assessment from the international body of literature regarding whether drivers recognise they are driving while fatigued, as well as if and why they continue to drive when they know they are fatigued, and what strategies they employed to mitigate fatigue

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND (road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (perce* OR aware* OR subjective OR inten* OR recogn* OR feel) AND ((continu* OR keep OR maintain OR persist) OR (mitigate* OR minimis* OR minimiz* OR reduc* OR manage*))
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 239**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (perce* OR aware* OR subjective OR inten* OR recogn* OR feel) AND ((continu* OR keep OR maintain OR persist) OR (mitigate* OR minimis* OR minimiz* OR reduc* OR manage*))
- 2000-2020, peer-reviewed, English
- **Total papers = 91**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":road OR "All Metadata":traffic OR "All Metadata":vehicle OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":car OR "All Metadata":"articulated vehicle" OR "All Metadata":automobile OR "All Metadata":motorcar OR "All Metadata":longhaul OR "All Metadata":long-haul) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata":perce* OR "All Metadata":aware* OR "All Metadata":subjective OR "All Metadata":inten* OR "All Metadata":recogn* OR "All Metadata":feel) AND (("All Metadata":continu* OR "All Metadata":keep OR "All Metadata":maintain OR "All Metadata":persist) OR ("All Metadata":mitigate* OR "All Metadata":minimis* OR "All Metadata":minimiz* OR "All Metadata":reduc* OR "All Metadata":manage*)))
- Year: 2000-2020, journal articles
- **Total papers = 177**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (road OR traffic OR vehicle* OR truck* OR bus OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (perce* OR aware* OR subjective OR inten* OR recogn* OR feel) AND TITLE-ABS-KEY ((continu* OR keep OR maintain OR persist) OR TITLE-ABS-KEY (mitigate* OR minimis* OR minimiz* OR reduc* OR manage*)) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 562**

Web of Science

- ((TS=driv*) AND (TS=(road OR traffic OR vehicle* OR truck* OR bus* OR car OR "articulated vehicle" OR automobile* OR motorcar OR longhaul OR long-haul)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (perce* OR aware* OR subjective OR inten* OR recogn* OR feel) AND ((continu* OR keep OR maintain OR persist) OR (mitigate* OR minimis* OR minimiz* OR reduc* OR manage*))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 576**

Topic 7

Identification from the international body of literature of any learnings from fatigue management in the heavy vehicle industry or other industries that could be relevant for light vehicle fleets

Search Terms (search conducted 9th June 2020)

PsycINFO

- (driv*) AND(“heavy vehicle” OR truck OR bus OR long-haul OR longhaul OR “long haul” OR transport*) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR “code of pract*” OR “codes of pract*” OR manage*))
- Title, Abstract, Keywords, 2000-2020, peer-reviewed, English
- **Total papers = 278**

Medline

- TI,AB,KW(driv*) AND TI,AB,KW((“heavy vehicle” OR truck OR bus OR long-haul OR longhaul OR “long haul” OR transport*) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR “code of pract*” OR “codes of pract*” OR manage*))
- 2000-2020, peer-reviewed, English
- **Total papers = 38**

IEEE Xplore

- ("All Metadata":driv* AND ("All Metadata":”heavy vehicle” OR "All Metadata":truck OR "All Metadata":bus OR "All Metadata":long-haul OR "All Metadata":longhaul OR "All Metadata": “long haul” OR "All Metadata":transport*) AND ("All Metadata":fatigue OR "All Metadata":sleep* OR "All Metadata":drows* OR "All Metadata":tired OR "All Metadata":alert*) AND ("All Metadata": polic* OR "All Metadata": arrangement* OR "All Metadata": law* OR "All Metadata": regulation* OR "All Metadata": legislation OR "All Metadata": guid* OR "All Metadata": “code of pract*” OR "All Metadata": “codes of pract*”)
- Year: 2000-2020, journal articles
- **Total papers = 102**

Scopus

- TITLE-ABS-KEY (driv*) AND TITLE-ABS-KEY (“heavy vehicle” OR truck OR bus OR long-haul OR longhaul OR “long haul” OR transport*) AND (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (fatigue* OR sleep* OR drows* OR tired OR alert*) AND TITLE-ABS-KEY (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR “code of pract*” OR “codes of pract*” OR manage*)) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000)) AND (LIMIT-TO (LANGUAGE , "English"))
- **Total papers = 742**

Web of Science

- ((TS=driv*) AND (TS=(“heavy vehicle” OR truck OR bus OR long-haul OR longhaul OR “long haul” OR transport*)) AND (TS=(fatigue* OR sleep* OR drows* OR tired OR alert*)) AND (polic* OR arrangement* OR law* OR regulation* OR legislation OR guid* OR “code of pract*” OR “codes of pract*” OR manage*))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
- Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2000-2020
- **Total papers = 470**

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