A literature review on driver fatigue among drivers in the general public

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S. McKernon
Supplejack Ltd, Auckland

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Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
research@nzta.govt.nz
www.nzta.govt.nz

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Abbreviations and acronyms

ACC	Accident Compensation Corporation
CPAP	Continuous positive airway pressure
DIDOW	Drive-in drive-out workforce
GDL	Graduated driver licensing
Land Transport NZ	Land Transport New Zealand
NRSC	National Road Safety Committee
RoSPA	Royal Society for the Prevention of Accidents

Contents

Executive summary

This report reviews the literature since 2000 on driver fatigue that is relevant to drivers in the general public.

Why conduct a review of general-public driver fatigue?

During 2007, the Minister of Transport requested that Land Transport New Zealand conduct a review of recent developments in international knowledge about measures to counter driver fatigue, with a focus on identifying which measures are successful, which are unsuccessful, and which could be workable in New Zealand in the future. The National Road Safety Committee (NRSC) also requested a similar review with the aim of profiling best practice suitable for the New Zealand context.

A Land Transport NZ and Accident Compensation Corporation (ACC) project team identified the 2001 report by the Royal Society for the Prevention of Accidents (RoSPA), entitled *Driver fatigue and road accidents: A literature review and position paper*, as a baseline review. As a result, the core aim of this review was to cover developments since 2000 (the final year covered in the RoSPA review).

The project team felt the scope of the review could be narrowed to better serve the immediate needs of Land Transport NZ and ACC, and to better explore recent developments in educational and behavioural change programmes. General-public driver fatigue poses significant challenges in terms of influencing general-public driver attitudes, skills and norms; for example, media campaigns targeting general-public drivers were viewed as important measures needing further exploration. As noted in this review, it can be difficult to assess and present evidence regarding measures for the general public, as various disciplines provide evidence using different conceptual frameworks and standards.

As a result, this review prioritises general-public driver fatigue over commercial-driver fatigue, and social change programmes over road engineering measures. It also makes every effort to integrate evidence for the success (or otherwise) of different measures from different disciplines.

What has the literature since 2000 added to our understanding of general-public driver fatigue?

Since 2000, the literature has moved on to explore:

- driver fatigue among young drivers
- the use of in-car technologies for fatigue detection and mitigation
- the combined effects of fatigue and alcohol
- the use of driver-intoxication indicators to set and communicate standards for fatigue.

A number of studies have also reviewed road safety programmes and suggested best practices for driver fatigue versions. Given these developments, it should be noted that all key measures against driver fatigue are already well known in New Zealand, and recent literature is largely concerned with understanding driver fatigue in more detail so as to deploy measures more effectively.

As a result, this review suggests further research is required to identify:

1. the scale and impacts of different types of fatigue for different groups of drivers, so as to identify strategic priorities for the smaller high-risk groups and the larger, lower-risk groups
2. an appropriate theoretical basis for programmes seeking significant social/behavioural change regarding driver fatigue

3. the specific fatigue problems and dynamics of target groups, so as to identify what measures match a given target group's problems, how to communicate effectively about their problems, and how to present appropriate measures
4. the design of programmes against driver fatigue, including measures against fatigue and indicators of success
5. avenues for developing driver fatigue regulation and enforcement.

What key measures are relevant to the New Zealand context?

This review distinguishes between fatigue arising from weariness through driving (*acute fatigue*) and drowsiness (*chronic fatigue*, typically arising from prior sleep deprivation). It also distinguishes between *interventions* (taken prior to or during driving, to address problems arising prior to driving) and *countermeasures* (taken during driving, to address problems arising during driving). This allows for more targeted measures against driver fatigue.

Acute fatigue may potentially affect all drivers, though especially vulnerable groups include holidaymakers/tourists, commuters, shift workers, the elderly and other commonplace groups. Programmes targeting these groups are 'positive' – they emphasise the need to stay alert/prevent acute fatigue with the benefits of alert driving. These may include media communications campaigns to educate drivers and build social norms, and the provision of road safety features such as rest areas and billboards/signs to remind drivers to stay alert and proactively manage fatigue. Media campaigns may be emotive (negative consequences or positive benefits may be used) but need to play a strong educational/informative role. Relevant measures supported by the literature are:

- music and trivia tasks to maintain and improve alertness
- caffeine (150 mg) – effective for 2 hours (slow-release caffeine may last longer)
- cooling the driving cab/lowering a window
- varying the car speed
- rumble strips
- persuasive, emotively laden media campaigns
- taking a break of 30 minutes or more – but the effects of this may only last up to 25 minutes for drivers who are seriously fatigued
- taking a short nap of up to 15 minutes – including caffeine with a nap is better
- taking 2 or more breaks during the trip
- sharing the driving
- in-car driver monitoring systems that warn drivers when they are fatigued.

Chronic fatigue is most frequently found among professional (truck, bus and taxi) drivers, sufferers of sleep disorders and young male drivers. Programmes targeting these groups are essentially 'negative' – they need to emphasise not driving while chronically fatigued (making it akin to drink-driving) and may include media communications campaigns to educate drivers and change peer group norms, regulation and enforcement, inclusion of anti-fatigue measures in graduated driver licensing (GDL), technologies such as alcohol locks, and provision of road safety features such as rest areas/rumble strips. Media campaigns may be strongly emotive (emphasising the negative consequences of driving while sleepy)

but must also provide positive actions drivers can take to prevent such consequences. Relevant measures supported by the literature are:

- having an average of 12–17 hours sleep in the 48 hours before travelling
- using a highway rest stop to nap for at least 15 minutes (though stopping driving is more fully supported)
- sharing the driving.

Regulation against chronically fatigued driving *per se* is suggested both within the literature and by advocacy groups within the community.

This report notes that acute and chronic fatigue are issues for different types of drivers – therefore, it follows that different measures are more likely to work for different types of fatigue and/or types of driver. Note that contradictory evidence for the efficacy of different measures can be clarified by separating out fatigue types and driver types. The tables below distinguish fatigue types and driver types to provide a framework for guiding decisions about which measures might be preferred and advised, and/or effective within a given programme.

In this report, *interventions* are measures taken *prior to or during driving,* to address problems arising prior to driving. The table following summarises the literature on interventions, relating the problems (acute versus chronic fatigue) to the driver groups most affected, to interventions used (both currently available and emerging), and to overall evidence for success.

Table 1 Different interventions in relation to key fatigue problems

Fatigue problems	Driver groups	Interventions	Evidence of success	Relative effectiveness
Lack of prior sleep/chronic fatigue	Groups associated with chronic sleep deprivation, especially truck and bus/coach drivers, shift workers, youth/young males	**Available** • Schedule activities • Alert driver to chronic fatigue • Reduce driver resistance to not driving/stopping to rest • Take naps; combine with caffeine if possible • Stop driving completely (voluntary and involuntary options) • Use TV and print media campaigns to educate	**Available** • Studies with commercial drivers show that integrated programmes can be successful • Studies show success with behavioural interventions with public drivers to prevent driving while chronically fatigued • Studies of drink-driving campaigns suggest accident rates can be reduced during a campaign, but different sub-	**Available** • Programmes can offset risks posed by fatigue (Morrow & Crum 2004, *Antecedents of fatigue, close calls, and crashes among commercial motor-vehicle drivers*) • Having an average of 12–17 hours sleep in the 48 hours before travelling (Cummings et al 2001, *Drowsiness, counter-measures to drowsiness, and the risk of a motor vehicle crash*) • A short nap of up to 15 mins, and caffeine with nap is better (Horne & Reyner 2001, *Sleep-related vehicle accidents: Some guides for road safety policies*)

Fatigue problems	Driver groups	Interventions	Evidence of success	Relative effectiveness
		drivers about chronic fatigue and measures against it	groups need different measures • Studies show GDL reduces injury-accident rates in young drivers, and fatigue is now included in GDL training programmes	• Sharing driving (Cummings et al 2001) • In-car driver monitoring technologies (Fairclough & Winsum 2000, *The influence of impairment feedback on driver behavior: A simulator study*) • Persuasive (emotively laden) media campaigns reduce crashes by 6–9% during a campaign and by about 15% afterwards (Delaney et al 2004, *A review of mass media campaigns in road safety*)
		Emerging • Prevent driving while chronically fatigued *per se* • Regulate against driving while chronically fatigued (with enforcement) • Use threat of legal, health and social consequences in media campaigns • Use anti-fatigued-driving training and elements in GDL schemes	**Emerging** • Studies of in-car fatigue detection technologies suggest driver alerting can be successful • Studies of GDL suggest interventions against chronic fatigue may be incorporated • No studies specifically on preventing chronic fatigue were identified in this review • No recent evidence of regulatory success identified by this review, though parallels with speeding and drink-driving suggest potential	**Emerging** • In-car driver monitoring technologies (Fairclough & Winsum 2000)

Fatigue problems	Driver groups	Interventions	Evidence of success	Relative effectiveness
			effects are significant	
Sleep disorders	Sufferers of sleep apnoea and other chronic disorders	• Continuous positive airway pressure (CPAP) • Medication	• Studies show CPAP and medication can reduce chronic fatigue and decrease risks while driving	• Continuous positive airway pressure (CPAP) reduces crash risk (Marshall et al 2003, *Obstructive sleep apnoea and risk of motor vehicle accident: A perspective*)

In this report, *countermeasures* are measures used *during driving* to address problems arising during driving.

The next table summarises the literature on countermeasures, relating the problems (acute fatigue) to driver groups most affected, to countermeasures used (both currently available and emerging), and to overall evidence for success.

Table 2 Different countermeasures in relation to key fatigue problems

Fatigue problems	Driver groups	Countermeasures	Evidence of success
Increasing weariness during travel/acute fatigue	• Groups vulnerable to acute fatigue symptoms eg work-related drivers, holiday drivers, commuters, older drivers • Truck drivers, bus/coach drivers, shift workers and other drivers where management of acute fatigue/ increasing impairment becomes an in-trip priority	**Available** • Maintain alertness • Drink caffeine • Play music • Vary vehicle speed • Vary in-vehicle temperature • Share the driving • In-car driver fatigue-detection technologies • Provide rest bays • Provide on-road alerts eg rumble strips • Provide crash safety features eg median barriers • Plan rest stops • Take rest stops (with caffeine) • Use TV and print media campaigns to educate drivers about fatigue and measures against it • Use radio and billboards to remind drivers of fatigue and to take measures against it	**Available** • Studies show each of these behavioural countermeasures can be successful if used for initial and early signs of fatigue/driver impairments • Studies also show that programmes using these countermeasures can be successful
		Emerging • Regulate against driving while chronically fatigued (with enforcement) • Use threat of legal, health and social consequences in media campaigns	**Emerging** • Studies of campaigns against excessive speed and drink-driving suggest fear-based campaigns could also work against driver fatigue, if messages include positive countermeasures

What might a best-practice programme look like?

In recent years, a number of researchers have reviewed the road safety literature, including that on driver fatigue, and have suggested elements of best practice for driver fatigue programmes. These elements are derived from programmes for speeding, drink-driving and seatbelt use, and further specific elements need to be developed for use in driver fatigue programmes.

Based on available evidence, key elements of successful programmes are:

- a central theory of behaviour change to focus programmes on the key influences on beliefs and behaviours
- clearly identifying a central problem – such as acute/in-trip fatigue or chronic/pre-trip sleep deprivation
- clearly identifying a target audience – such as smaller, higher-risk groups (eg young male drivers) or larger, lower-risk groups (eg commuters or holiday travellers)
- providing strong, emotive media messages, with linked behaviours (to gain benefits and/or escape negative consequences)
- using broadly based publicity/public relations/editorial to support any programme (ie unpaid media activity), if possible in combination with enforcement
- developing programmes that use multiple measures (rather than relying on short-term, ad hoc or 'silver bullet' programmes to effect change) – may include media campaigns, regulations and enforcement, training, roadside rest areas, and signage prompting drivers to check their fatigue levels (and stop if necessary, or use in-car technologies to achieve this). Driver fatigue measures may also be included in graduated driver licensing.

The research reviewers note that appropriate success indicators must also be developed to accurately assess change. This is especially important where the ultimate indicator is behavioural change.

Abstract

The New Zealand government is seeking to reduce the number of road crashes that arise from driver fatigue in this country. To this end, Land Transport New Zealand commissioned a review of international driver fatigue literature (2000–2007) to assess measures against driver fatigue that would be effective for general public drivers.

The review first notes that a number of disciplines study driver fatigue, each using its own definitions and so emphasising different measures. This constrains the development of measures and longer-term programmes for the general public. The review thus notes the need for evidence-based theory specific to general-public driver fatigue. This would enable clearer understanding and facilitate the design, management and evaluation of programmes.

This review distinguishes between fatigue from weariness through driving (acute fatigue) and fatigue from prior sleep deprivation (chronic fatigue). It also distinguishes between interventions (measures used prior to driving) and countermeasures (measures used during driving).

It then links specific fatigue problems (acute or chronic), as experienced by specific driver groups, to the most effective measures against them (interventions or countermeasures) for that driver group.

Finally, it suggests a guideline for best practice in the design of measures and programmes to counter driver fatigue within the general public.

1 Introduction

This section provides a background to driver fatigue research and to common interventions and countermeasures. It also introduces and defines key concepts used in this report.

1.1 Background

Driver fatigue is a major contributing factor to road crashes in New Zealand. In 2007, fatigue was identified as a contributing factor in 48 fatal crashes, 130 serious-injury crashes and 554 minor-injury crashes. These crashes resulted in 54 deaths, 188 serious injuries and 798 minor injuries. The total social cost of crashes involving driver fatigue was about $332 million – that is, about 9 percent of the social cost associated with all injury crashes. However, fatigue is difficult to detect and recognise as having a role in a crash, and research suggests that the contribution of fatigue to crashes may be under-represented.

If the government's target of reducing the number of people killed and seriously injured in road crashes to no more than 300 per annum by the year 2010 is to be achieved, then driver fatigue is an important area of driver behaviour that needs to be addressed.

During 2007, the then Minister of Transport requested that Land Transport New Zealand conduct a review of recent developments in international knowledge about measures to counter driver fatigue. This review was to focus on identifying measures that were successful, those that were unsuccessful, and to summarise any that could be workable in New Zealand in the future. The National Road Safety Committee (NRSC) requested a similar review with the aim of profiling best practice suitable for the New Zealand context.

A Land Transport NZ/Accident Compensation Corporation (ACC) project team identified the 2001 report by the Royal Society for the Prevention of Accidents (RoSPA), entitled *Driver fatigue and road accidents: A literature review and position paper*, as a baseline review, and commissioned a project to review more recent published research on:

- driver fatigue countermeasures that target general drivers
- new technological developments
- unsuccessful countermeasures.

The project team felt the scope of the review could be narrowed to better serve the immediate needs of Land Transport NZ and ACC, and to better explore recent developments in educational and behavioural change programmes. General-public driver fatigue poses significant challenges in terms of influencing general-public driver attitudes, skills and norms; for example, media campaigns targeting general-public drivers were viewed as important measures needing further exploration. As noted in this review, it can be difficult to assess and present evidence regarding measures for the general public, as various disciplines (such as health-based studies, crash analyses and road safety campaign assessments) provide evidence using different conceptual frameworks and standards.

As a result, this review prioritises general-public driver fatigue over commercial-driver fatigue, and social change programmes over road engineering measures. It also makes every effort to integrate evidence for the success (or otherwise) of different measures from different disciplines.

This report covers research published since the year 2000 (the final year covered in the RoSPA review), and is primarily a review of research relating to fatigue countermeasures that are aimed at the driver. It

should be noted that this report addresses an important subset of the fatigue literature and the potential intervention/countermeasure literature – but some measures, such as engineering countermeasures that are aimed at the general road user, but which can also influence fatigued driving, are not discussed in detail in this report.

1.2 Review aims

The specific scope and aims of this literature review were to:

- review the international literature, from 2000 to the end of 2007, on driver fatigue among drivers in the general public (including workplace interventions), with related interventions (including new technological developments)
- identify interventions for this group that could be used successfully in New Zealand
- identify unsuccessful interventions (in as much as they may not be used successfully in the New Zealand context).

The review excluded causes and incidence of driver fatigue and interventions for heavy-vehicle commercial drivers. However, some reference to both was required to address the review aims appropriately.

In other words, while the review was apparently an update of driver fatigue literature since 2000, the scope of the review was actually strongly oriented towards the general public and to interventions appropriate to this group.

1.3 Review method

The method for this review is described below.

1.3.1 Search strategy

The general search strategy was to move from the general to the specific, using the RoSPA review of 1999 as a starting-point:

1. Trace citations of articles/authors in the RoSPA review and establish generic search terms. Some 40 potential articles and books/book chapters were identified by this means.
2. Search for literature after 2000 to the end of 2007, using generic search terms to identify new/other key articles and authors (by general level of citation). Generic terms were ‘driver fatigue’, ‘driver drowsiness’, ‘drowsy driving’ and ‘sleepy driving’. Some 160 potential books/book chapters and articles were sourced by this means.
3. Search for literature after 2000 to the end of 2007 for specific topics/authors. A wide range of topics/authors was used here. Some 50 potential books/book chapters and articles were sourced by this means.

That is, a total of about 250 potential books and articles were identified and their abstracts read, before narrowing these to a shorter list of articles.

Books, book chapters and articles were then skim-read to assess their relevance, and worthwhile citations were checked. Thus, some were added (as suggested by citations) while others were culled. This narrowed the list to 125 books, book chapters and articles.

As a final step, some articles were culled during writing, as it became clear they did not contribute substantially to the review. The result is that about 90 articles were used in the review, spanning the period from January 2000 to December 2007 inclusive.

1.3.2 Databases

For generic searches, generic search engines (ProQuest, Google Scholar) were used to quickly scope the literature and key databases.

Once key authors/topics were identified, specific electronic library and publishing databases were used, including:

- Elsevier/ScienceDirect
- Publishing Technology/IngentaConnect
- Sage/Sage Journals Online
- San Diego State University and World Health Organisation/SafetyLit
- US National Library of Medicine and National Institutes of Health/PubMed
- Routledge & Taylor/informaworld
- IEEE/IEEE Xplore
- EBSCO/EBSCOhost
- a range of other sources, including the Ministry of Transport/Land Transport NZ, and transport ministry websites in Australia, the UK, the US and Canada.

As might be expected, there were considerable overlaps between these sources.

2 Definitions used in this report

The driver fatigue literature uses a number of definitions, largely because research derives from three very different research traditions: experimental, differential crash rate, and automation research.

For example, the NRSC's *Driver fatigue strategy* (2007, p. 3) included four different definitions:

1. fatigue arising from driving for a long time, where the longer the driver continues, the more fatigued he/she becomes
2. fatigue related to the time of day and circadian rhythms, which predispose drivers to sleepiness between 3 am and 5 am and 3 pm and 5 pm
3. fatigue arising from sleep debt, where a person has been deprived of sleep within the 24 hours prior to driving
4. fatigue arising from illness (such as sleep apnoea) or medication, so that a person's driving is actively impaired.

The NRSC also noted that:

- one or more of the above may contribute to overall fatigue
- other issues (such as stress or fatigue from work) may also be factors
- alcohol and recreational drugs can exacerbate any fatigue.

Fatigue is, therefore, a complex construct.

This leads to a range of differing (and sometimes contradictory) criteria for driver fatigue and related driver impairments (Brill et al 2003; Brookhuis et al 2003; MacLean et al 2003; Trick et al 2004). As a result, clear evidence for the impacts of different measures against fatigued driving is difficult to assemble.

For example, in their review of the literature, New Zealand sleep researchers Connor et al (2001b) concluded that direct evidence for fatigue as a cause of car crashes was weak (aside from specific sleep disorders). It follows that any programmes to address driver fatigue have the triple burden of defining the specific type of fatigue being addressed, constructing appropriate measures, and then providing evidence of success. Mixed and contradictory results are inevitable.

In these circumstances, it is difficult to trace links between specific fatigue definitions and specific anti-fatigue measures. That is, it is difficult to identify the rationale for using one measure over another, and in particular, for using a specific measure against a specific type of fatigue.

For example, the NRSC *Driver fatigue strategy* (p. 5) proposed three broad interventions:

1. engineering – improving road infrastructure to prevent crashes and reduce their severity
2. education – teaching drivers to avoid and manage the risks of driver fatigue, eg through planning trips or introducing workplace programmes
3. enforcement – enforcing regulations that reduce driving while fatigued, and improving investigation of accidents that may have involved fatigue.

These were proposed without a rationale for their choice, and in context, it was clearly very difficult for NRSC to provide such a rationale. Rather, the NRSC opted for the pragmatic three-strand mix of general interventions that seem most likely to prevent fatigued driving and/or reduce its effects overall. The

Ministry of Transport's strategy document *Road safety to 2010* (2003) also emphasised a combination of measures across engineering, education and enforcement. It follows that programmes such as fatigue-management rules for commercial drivers, and the installation of median cable barriers, will reduce the incidence and impact of driver fatigue.

Because this review was specifically concerned with identifying successful (and unsuccessful) measures against general-public driver fatigue, it organised the literature in terms of possible measures, rather than in the terms of the disciplines represented (such as the very different disciplines relating to road engineering, public education and crash analysis). Definitions used in this report were based on Fletcher et al's (2004) distinction between 'reducing the likelihood of fatigue' (interventions) and 'reducing the consequences of fatigue' (countermeasures).

This meant that some reference to heavy-vehicle drivers was required to source examples of well-integrated and proven programmes, given that such examples were scarce. On the other hand, it resulted in limited reference to road engineering measures, as preventing general-public driver fatigue is often not their focus (although preventing and mitigating crashes is an obvious benefit). Examples of unsuccessful measures were also rare. Note that many best-practice driver fatigue research and implementation programmes were Australian, which allows some cultural similarities.

As evidenced above, the emphasis on measures also resulted in rather more discussion of results than expected in a literature review of this type. One reason was that problems with the definition of driver fatigue *per se* made it difficult to articulate which measures were best in relation to different fatigue problems and types of drivers. Another reason was that driver fatigue measures themselves are evolving, as the various disciplines contribute to their success.

This review, therefore, began by constructing more specific, measure-oriented definitions from available evidence. The aim was to organise types of measures in relation to types of driver fatigue and drivers found within the general public. The proposing of definitions in the context of a fragmented literature, and at the start of the review, may seem to pre-empt findings and preclude alternate views. But without such an approach, it was difficult to provide a review that adequately meets the emphasis on measures. As a result, the definitions below were scoped with Land Transport NZ and ACC to ensure their salience and practicality, as well as being grounded in the literature.

2.1 Fatigue problems: Alert – acute – chronic

As indicated above, researchers note the concept of 'driver fatigue' is variously defined, ranging from a lack of alertness (intermittent mismatches of cognitive functioning with driving tasks) through to drowsiness (a significant and chronic change in the driver's psycho-physiological state). This study used a three-part definition to maximise opportunities for measures against fatigue:

1. Alertness – This is an implicit ideal, so maintaining alertness is important to the prevention of driver fatigue.
2. Acute fatigue – Driver fatigue can arise because of driving tasks and the duration of a trip, so recognising early signs of fatigue is important to preventing further impairment and increasing fatigue.
3. Chronic fatigue – Driver drowsiness and sleepiness result in serious driver impairment, so preventing chronic fatigue means stopping driving until the fatigue has passed.

While this three-part definition is not fully developed in the literature, it is often implicit in the definitions provided (eg in the NRSC *Driver fatigue strategy*, 2007), and some researchers distinguish

acute from chronic fatigue (eg Oron-Gilad and Hancock 2005). In the context of this review, the intervention-oriented definitions are therefore accurate and provide a means of linking types of fatigue to specific measures. That is, the approach provides a rationale for selecting one measure over others and relative to the types of fatigue characteristic of specific target groups.

Note that in practice, the definitions above are not mutually exclusive and may be affected by factors that accentuate fatigue, such as time of day (ie the effects of circadian rhythms), trip duration, and alcohol and/or drugs. For example, a shift-worker making a long drive home at 4 am may be affected by acute fatigue (from trip duration and monotony), chronic fatigue (from stress at work and lack of sleep in previous days) and by the 3 am–5 am ebb in his/her circadian rhythm. For this reason, it is also important to consider the type of driver *per se* – the target group for the intervention. That is, different interventions are appropriate to different drivers because they are likely to be exposed to distinct fatigue types and mixes.

2.2 Targets: Driver groups

There is frequent reference in the literature to different drivers with their different experiences of fatigue and different levels of associated risk. It is, therefore, important to indicate the specific type of fatigue and driver when constructing measures. The different driver groups used here are merely the demographic groups appearing across studies as the researchers' key groups of interest – such as commercial drivers, younger drivers and older drivers – but others may also exist.

Measures against fatigue necessarily focus on the fatigue problems experienced by a specific group of drivers. For example, a programme against fatigue in young male drivers, who have significant problems with both sleep deprivation and alcohol consumption while driving, is necessarily different from a programme against fatigue in elderly drivers, who may be most vulnerable to acute fatigue.

2.3 Measures: Intervention/countermeasure

Measures against driver fatigue are also variously defined in the literature. The definitions below clarify two core strategies and are used throughout this review. Note that they emphasise actions undertaken by transport agencies (rather than by individual drivers). The focus is on measures that encourage changes in public driver attitudes, behaviours and norms in relation to fatigue and driving.

- An *intervention* is a measure that prevents driver fatigue, and so involves the promotion of actions taken before a trip to maximise pre-trip sleep/rest and to minimise in-trip fatigue. Interventions may occur via driver behaviour (such as driver preparation) as well as in the roading environment (such as provision for rest during long trips, or design of roading infrastructure to help maintain alertness).
- A *countermeasure* is a measure that minimises or counters driver fatigue during a trip, and can include promotion of exercises to maintain alertness, and stopping the trip for sleep. A countermeasure may depend on the driver recognising the early signs of decreasing alertness or acute fatigue and then acting appropriately. Countermeasures may occur through monitoring technologies (that identify early warning signs), through driver behaviours (such as changing drivers), and through roading design (such as rumble strips). Note that countermeasures may include harm mitigation, such as roadside hazard removal and other road engineering solutions, though these are not a focus in this review. As noted in subsequent sections, in-car technologies may also have a role in mitigating harm.

While these definitions suggest mutual exclusivity, an integrated programme requires both, and in particular, interventions require countermeasures to be fully effective. Furthermore, other measures such as road and vehicle design and enforcement programmes must also be considered.

For example, a holiday road safety programme might:

1. encourage drivers to plan for rest stops as part of a trip
2. provide frequent rest stops on main routes
3. educate drivers about using them in a timely way
4. give drivers on-road (billboards) and in-car cues (stickers) to remind them to stop
5. give drivers self-assessment tools to help them recognise fatigue
6. enforce speed limits and include fatigue questions at police checkpoints.

2.4 Framework: Driver type – fatigue problems – measures

Frameworks for organising appropriate measures against driver fatigue are not clearly defined in the literature. The key reason is simply that driver fatigue is poorly defined, so measures are often generic (rather than specific to the type of fatigue, type of driver, and so on). As a result, appropriate evidence of success, and the relative effectiveness of one measure compared to another, is often difficult to define and measure.

Because this review was oriented specifically to measures, it was critical that a framework was proposed, if only to prompt further development. New Zealand needs a framework appropriate to the geography of its transport network, which may involve different types of fatigue across both urban (eg commuter drivers) and rural (eg holiday drivers) settings. Note the measures discussed here are not exhaustive, and the aim of the review was to explore public-driver educational measures in particular.

The framework below was proposed for assessing specific types of fatigue, appropriate measures against them, and evidence for their success or failure, with their relative effectiveness.

Table 2.1 Assessment of specific types of fatigue

Driver group	Fatigue problems	Measures	Evidence of success	Relative effectiveness
Different drivers experience different risks and injury crash rates.	Fatigue problems specific to the driver group are characterised here.	Measures specific to the driver group and/or fatigue problems are detailed here.	Evidence of success of measures appropriate to a specific group and/or measure is provided here.	Evidence of the relative effectiveness of different measures is provided here.

This framework is referred to throughout this review to help identify developments in the understanding of driver fatigue and measures more likely to achieve success in New Zealand.

3 Driver fatigue problems and measures

This section reviews recent research on specific fatigue-related problems.

3.1 Maintaining alertness

The concept of driver alertness is not a common focus in driver fatigue literature (it is more prominent in inattention/distraction studies), but measures to maintain driver alertness overlap with measures to manage acute fatigue. This indicates that simple measures may manage both.

For example, Verwey and Zaidel (1999) found that over a sustained period, a game-like task maintained higher driver alertness compared with a control group, and Oron-Gilad et al (2007) found that professional drivers were most alert when mentally engaged with a trivia task, enjoying this most out of all the tasks tested. Dibben and Williamson (2007) found that listening to music while driving was very common, and some types of music were associated with better safety records.

Brice and Smith (2001) found that caffeine was effective for maintaining alertness and for restoring alertness during sustained tasks, while De Valck et al (2003) found more sustained effects with slow-release caffeine. Similar results were found for caffeinated energy drinks.

Landstrom (2006) found that cooling the temperature inside a vehicle by 5–10 degrees for 5–8 minutes resulted in a consistently positive effect on driver alertness. While drivers might be able to achieve similar effects by opening windows, the author suggested vehicle technologies could incorporate a variable cooling system. Tejero and Chóliz (2002) found that decreasing alertness because of highway monotony could be countered by varying the vehicle speed, while Thiffault and Bergeron (2003) suggested improved roading design as another means of countering monotony.

Note that work by Oron-Gilad and Hancock (2007) suggested that most driving time is undemanding and does not require a driver's full attentional capacity. Under such circumstances, alertness is relatively easy to maintain. But the authors found that different road types required different strategies for maintaining alertness – for example, straight roads led to much greater deterioration in driver alertness and behaviour than curving roads. They cautioned that stand-alone measures may be undermined by different road designs and/or the different ways drivers adjust to these.

Overall, it appears that simple disruptions to monotony, plus low-key mental tasks to stimulate driver alertness, are useful countermeasures when fatigue levels are relatively low. These may include design of roading infrastructure to disrupt monotony. Note that disruptions to monotony are not clearly distinguishable from distractions, and further work may be required to understand optimal disruptions. Interventions to educate drivers in their use might easily be included in all basic driver training and could be used in generic driver safety campaigns.

3.2 Managing acute fatigue

The notion of managing impairment is used in the literature in two very different contexts, though these are poorly distinguished:

1. driving while sleep-deprived (impaired prior to driving)
2. driving with increasing fatigue (impairment increasing while driving).

This distinction is important because sleep deprivation precludes completely safe driving, while increasing/acute fatigue is associated with low, but increasing, impairment. The latter may feature widely across different driving contexts and, therefore, offers many opportunities for preventing driver fatigue.

Recent clinical studies (Pigeon et al 2003; Shen et al 2006) noted the confusion of acute fatigue with chronic fatigue in both medical and driver fatigue literatures, and argued that these are distinct phenomena. They defined *chronic fatigue* as 'lowered arousal and the high likelihood of falling asleep', or as 'prior sleep deprivation and chronic fatigue', and defined *acute fatigue* as 'tiredness and depleted energy and the effect of sustained exertion, and is task-related'. Therefore, this report uses the term 'fatigue' as the generic, and 'acute fatigue' and 'chronic fatigue' as distinct types of fatigue. As noted below, recent studies suggest that acute fatigue (though often lesser in its effects) occurs in a much larger proportion of the population than does chronic fatigue.

3.2.1 Initial and increasing driver fatigue

Philip et al (2005) found that acute and chronic fatigue had very different effects on driving, with chronically fatigued drivers performing far worse and with greater inter-individual differences. They argued that safety campaigns should focus on chronic fatigue as the more serious condition, even for relatively short trips, especially if drivers already felt sleepy.

Yet the evidence suggests that acute fatigue is far more prevalent than the chronic type. For example, large, commonplace driver groups, such as commuters, work-related drivers and holiday drivers, are likely to experience acute fatigue independent of prior sleep. Cummings et al (2001) found crash risk increased exponentially in relation to increases in driving time, indicating that acute fatigue is a key contributor to risk.

In New Zealand, for example, Connor et al (2001a) found chronic fatigue (arising from sleep deprivation) in only 3.1 percent of drivers, though a much larger proportion (21.9 percent) had had fewer than five full nights of sleep in the previous week. The authors noted that the prevalence of significant sleep deprivation was lower than suggested by previous studies. On balance the larger causes of fatigue would seem to be minor chronic fatigue and acute fatigue. On this basis, the opportunity to target acute fatigue was significant, since it was present in nearly a fifth of drivers.

The dynamics of acute fatigue have also been explored recently in the New Zealand context. Smith et al (2006) found that crashes along the Kaikoura coast were highest on straight, easy roads and after drivers had descended from hilly sections requiring higher concentration. Low-grade impairments resulting from acute fatigue, temporary relaxation and driver 'hypnosis' (Parliamentary Travelsafe Committee 2005) can contribute significantly to accidents once driver alertness is lowered.

The literature notes four broad sources of acute fatigue and increasing trip-based fatigue, namely:

- trip tiredness *per se*, such as mental and physical fatigue during a long trip
- under-stimulation or 'highway hypnosis', which arises from the combination of car comforts, trip monotony and car/road vibration
- time of day/circadian rhythm effects (which are significant during peak commuting times (eg between 3 pm and 6 pm)
- background fatigue, such as from prior mental and physical fatigue (eg from a work day – although in the context of this review, this is actually an example of chronic fatigue.

Measures against acute fatigue are important because they address fatigue in its initial stages and may also help prevent driving with chronic fatigue. They are also important because they overlap with

alertness-maintaining measures, and so reinforce proactive driving. As noted, various researchers have shown that caffeine is consumed both to maintain alertness and when drivers notice increasing impairment.

Other measures, in rough order of *actual* driver behaviour (albeit self-reported), include opening a window, stopping and walking, playing music, talking/singing to oneself, eating/drinking (water, energy drink or coffee), talking with a passenger, stopping to nap, stopping to eat, and talking on a cell phone (Nordbakke and Sagberg 2007).

This study also indicated that driver beliefs differ from actual practices. In rough order of driver *preference*, measures were swapping drivers, stopping and walking, stopping to nap, opening a window, talking with a passenger, stopping to eat, drinking/eating, putting on music, talking/singing to oneself and talking on a cell phone. That is, in-car measures were generally preferred.

The authors noted that the actions considered most effective – stopping and getting out of the car (whether to eat, nap or walk), or, where another driver was available, swapping drivers – were largely those least used. Stopping for any other reason apart from taking a walk, and swapping drivers, were not popular. Older people (over 40 years of age) were more likely to use these measures.

As discussed in the next section, studies typically show that drivers are familiar with the signs of acute and chronic fatigue, but typically minimise or ignore them. Fletcher et al (2005) suggested drivers resist taking measures because of:

- a poor understanding of the risks of fatigue
- poor knowledge about the speed of onset of fatigue
- no personal history of significant experience of impairment by fatigue
- ignoring warning signs
- pressure to reach a destination
- no threat of dire consequences.

The in-trip timing of any measures is clearly important. Horne and Reyner (2001) suggested that once drivers were significantly impaired/chronically fatigued, measures such as rolling down a window for fresh air were effective only long enough to enable the driver to find a place to rest. That is, measures might work in maintaining alertness and managing acute fatigue when it was first noticed, but were ineffective when drivers were more seriously fatigued. As noted below, the only effective solution in these cases is to stop driving and rest.

The key problem is that fatigue disrupts drivers' cognitive functions. Horne and Reyner (2001) found that drivers became aware of fatigue-related impairment, but usually underestimated its effects and/or undertook measures too late to address them. Vick (2006) found that drivers treated longer journeys as a challenge. They prioritised the journey's end over in-journey tasks, and minimised issues such as fatigue to the extent that increasing fatigue was resisted (as a barrier to arrival) rather than managed (through skills within good driving). Horne et al (2001) have, therefore, argued for behavioural interventions such as permanent signs on motorways to compensate for drivers' cognitive lapses, thus managing acute fatigue in its early stages when cognitive functioning was still adequate.

3.2.2 Driver fatigue detection and related technologies

Desmond and Matthews (1997) found that fatigue degraded a driver's awareness of his/her performance, though not the ability to compensate once a driver noticed any impairment. They argued that measures

must first alert drivers to the onset of impairment, and that in-car fatigue detection technologies were the most appropriate measure.

Fairclough and Winsum (2000) noted that technological feedback systems alerted drivers to driving impairments, but failed to prevent drivers from continuing their trips, or to alter drivers' subjective responses to the fatigue in order to secure management of impairments/fatigue itself. MacLean et al (2003) added that the technologies are also limited by their:

- orientation to chronic fatigue only (as opposed to varied types of fatigue)
- difficulty accounting for individual differences (such as driver passivity or aggression)
- difficulty with driver responses to different contexts (such as urban rush hour versus rural travel).

Given the above issues, recent studies indicate significant progress towards practical solutions applicable to general-public drivers. For example, Wright et al (2007) reviewed 25 different fatigue-detection systems using a range of technologies, and concluded that 15 were worthy of further evaluation. These 15 included systems based on tracking eye movement, steering/lane deviations, fatigue calculators, and ones based on a mix of systems.

Perhaps the most advanced example is provided by the Center for Intelligent Systems Research (2007), which recently endorsed a driver fatigue detection system for truck drivers. It is based on an earlier system that was based on steering inputs only, and has been developed for general-public drivers. Unlike systems based on eye tracking, a system based on steering inputs is unobtrusive, relatively cheap and simple to install, and is not limited by low-light conditions or when drivers wear glasses. While there are some (increasingly minor) problems with false positives and negatives with such systems, the warning rate before potential crashes was virtually ideal. The success of the system rests in the use of artificial neural networks to help identify, learn and warn against fatigued driving patterns.

In context, in-car driver fatigue detection and warning technologies are now a reality, and as they are commercialised, will become increasingly viable as measures available to larger numbers of drivers. Key issues as noted are driver acceptance of these devices, and more importantly, that more responsible drivers appear more likely to install them.

A range of technologies are being developed under the general rubric of driver aids. These are vehicle-management systems (including fatigue monitoring, forward-collision monitoring, lane-departure warning, emergency notification and intelligent speed adaptation) and driver-access systems (including the alcohol interlock and the electronic licence). Mitsopoulos et al (2002) found that such devices were accepted by Australian drivers from higher-risk groups if their main use was to alert drivers to hazards and driver impairments. Devices were rejected when they reduced driver control, even when the aim in doing so was to secure driver/vehicle safety. This also meant that the devices offering the greatest safety benefits (the alcohol interlock, electronic licence and intelligent speed adaptation devices) were least accepted by drivers.

3.2.3 Road-based alerting systems

Road-based driver alerting systems are also frequently proposed, the most common being centreline rumble strips, median barriers/rumble strips and rest bays. For example, as noted above, Horne and Reyner (2001) have argued for road-based systems to compensate for drivers' cognitive lapses.

A thesis by Govendar (2006) found evidence for the usefulness of all three roading measures in a study of State Highway 1 south of Whangarei.

A cost-benefit study of rumble strips by Mackie and Baas (2007) noted that the crash reduction factor of 25 percent (derived from US studies) was applicable to New Zealand conditions. Stutts et al (2005) suggested that roading treatments such as rest stops were also effective, though crash reduction study data were not yet available. The US standard appeared to be a rest stop per every 80 km or 1 hour of driving, with preference for those providing coffee and other comforts that encouraged a significant rest.

These various treatments were generally not found in urban areas except on motorways as, for example, rumble strips could result in excessive road noise in residential areas. The study argued for installing rumble strips on all roads that afforded a shoulder of 1.5 m or more and were not likely to cause noise problems for local residents.

Road-based systems relevant to urban drivers (most general-public drivers) are, therefore, an area of possible development.

Note that other in-car and on-road harm mitigation approaches are available, such as 'intelligent' vehicle braking systems and wire-rope median barriers. The full range of such solutions is not the primary focus of this review.

3.2.4 Driver fatigue, impairment and alcohol

Recent work on driver fatigue has begun to quantify its effects, using drinking-related impairment as a point of reference. Studies by Williamson and Feyer (2000) and Arnedt et al (2001) found that moderate sleep deprivation produced impairments at levels similar to those found with moderate alcohol consumption. Horne et al (2003) found that blood alcohol levels below the UK legal driving limit significantly increased fatigue-related impairments in young men, though these drivers were not aware of the effect. Barrett et al (2004) noted that moderate (legally safe) blood alcohol levels markedly worsened fatigue-impaired driving in women. However, women were also more aware of, and better able to, judge driving impairments than men, which could explain women's lower fatigue-related accident rates. Maruff et al (2005) found that after 24 hours of sleep deprivation, driving impairment was equivalent to a 0.05 percent blood alcohol content.

There is some difficulty with this approach in accounting for impairments arising from acute fatigue, which may equate to lower levels of impairment on the one hand, and to more common types of impairment on the other. That is, comparison with intoxication appears to be a useful approach, but needs to be more clearly related to different types of fatigue.

Given that impairment affects both driving and decision-making skills, it appears that measures need to mix social and behavioural interventions (such as education designed to change fatigue norms and to encourage trip planning behaviour) with in-car countermeasures (prompts to check for signs of fatigue or to act immediately when these are noticed). In the driver fatigue context, both social research and social marketing programmes against drink-driving (which use such combined measures) may offer useful models.

3.2.5 Examples from speed and drink-driving measures

Haworth's (2003) review of road safety programme evaluations worldwide found that mean effect sizes ranged from 7.6 percent to about 14.8 percent, noting that:

- localised programmes achieved larger effects than national ones

- speed campaigns achieved greater effects than drink-driving campaigns
- longer-term campaigns had greater effects than shorter-term ones.

The author also cited a reduction in road deaths in Victoria of up to 40 percent between 1989 and 1996 – the road safety programmes that had the most influence on this were speed camera fines and drink-driving campaigns. Increasing unemployment was also significant. These findings were supported by studies and guidelines in the US (Stutts et al 2005), which emphasised the need for long-running, multi-faceted programmes.

Asbridge et al (2004) noted that Canadian programmes showed positive effects for specific programmes as well as a longer-term effect. The programmes variously combined legal measures, public information and education campaigns, rehabilitative programmes for convicted drivers, and technological aids to the prevention and detection of fatigue. In particular, the Breathalyser Law in Ontario was associated with an estimated reduction of 18 percent in the number of fatally injured drinking drivers. Work by Tay (2005b) suggested similar results internationally, with a median drop in injury-crash numbers of 10 percent and cost–benefit ratios ranging from 1:8 to 1:21.

Lewis et al (2007) noted the mixed success of fear-based approaches in road safety advertising, after decades of use, and found that one reason for this was that women might respond behaviourally to campaigns featuring physical harm, but men did not. They suggested that targeting by gender was important in the design of a campaign. They noted that the impact of such fear-based approaches on driving behaviours increased when campaigns included actions that drivers could take to correct poor driving behaviours, and to protect themselves from the consequences of harmful actions.

In a review of media campaign studies, Delaney et al (2004) noted the integration of diverse social and behavioural change approaches within road safety programmes as the discipline matures. For example, programme development in recent years has featured the inclusion of behaviour-based approaches from the new discipline of social marketing. Their review of research on the effectiveness of campaigns noted the difficulty of separating causal and confounding variables in retrospective studies.

Given this issue, their review suggested:

- persuasion-based (emotively laden) media campaigns appeared to reduce crashes by 6–9 percent during the campaign period, and by about 15 percent afterwards
- enforcement on its own might contribute a 7 percent reduction
- legislation might contribute a 17 percent reduction
- a theoretically based campaign reduced crashes by 20 percent.

Elliott and Armitage (2006) found that asking drivers to commit to self-imposed road-speed compliance targets had a positive effect when later assessed. Parallel work has been done by Lenné et al (2004) to identify potential driver fatigue measures emerging within experimental psychology. That is, a programme may address knowledge/beliefs and behaviours simultaneously, as is the case with campaigns mixing emotive messages with information about protective behaviours.

An issue with these approaches is the use of a wider range of indicators than impact on numbers of crashes/crash rates. Aside from the work of Tay (2005a, 2005b), there is limited evidence in the Australasian context for the impact of media campaigns on crash rates.

3.2.6 Programmes against acute fatigue

Fletcher et al (2005) suggested driver fatigue was not given the attention it deserved in research or safety programmes, despite its influence on accident rates in Australasia. They argued for driver education campaigns that personalised the risk to drivers, and for simple standards and guides that would help drivers assess their own level of fatigue. They also argued that the legal consequences of driving when fatigued needed to be defined, legislated and enforced, and that further research was needed to understand optimal ways of combating fatigued driving and related programme design.

In the absence of regulation, other measures against driver fatigue cannot be expected to have significant and sustained effects at the levels seen in programmes targeting speeding, drink-driving and wearing seatbelts. An orientation to managing acute fatigue provides drivers with the opportunity to act on the early signs of fatigue while cognitive functioning is still strong, and many commonly cited in-car measures are effective in this context. To make sure drivers are primed to use these effectively, measures would need to mix educational interventions with in-car/en-route countermeasures, such as prompts to help drivers recognise the signs of acute fatigue and be proactive in taking measures against it.

Finally, Gander et al (2005a) noted that educational interventions addressing impairment are often advocated but rarely evaluated. The authors assessed truck drivers up to two years after a training programme and found that:

- most knowledge had been retained
- most drivers had benefited from the training
- a significant group had used measures successfully (at home and work)
- safety was an important part of driver culture.

That is, the limited evidence of success with fatigue impairment-oriented programmes was a function of programme conduct and evaluation, not of the educational strategy itself.

3.3 Combating chronic fatigue

It is clear from the above review that chronic fatigue/sleepiness occurs within the driver fatigue literature, as both a general term and as an extreme, in two distinct ways – as a state prior to getting into the car (prior sleep deprivation) and as a state immediately prior to 'falling asleep at the wheel'. Both are significant, because chronically fatigued/drowsy/sleepy drivers have discounted all earlier signs of fatigue, including obvious impairments, to continue driving.

The key measures proposed in the literature are to ensure adequate sleep prior to travel, and to stop driving in order to have a rest. For example, Cummings et al (2001) noted that crash rates were lowest for those who had had a total of 12–17 hours of sleep within the 48 hours prior to driving – though they also noted that both less, and more, sleep than this were associated with higher risk, perhaps because sleeping more indicates an attempt to recover from a chronic lack of sleep. Citing Belenky et al (2003), Grunstein et al (2004) noted that 'catch-up' sleep following chronic sleep deprivation does not return people to their baseline. This highlights difficulties with the notion of driving while chronically fatigued, as the evidence indicates that many drivers with this level of impairment should not be driving at all.

In addition, Nguyen et al (1998) noted that the case for stopping and napping during a trip relied on evidence of lower crash rates (in epidemiological studies) and reversal of chronic

fatigue/sleepiness/drowsiness (in simulator studies). They argued that the evidence of significantly improved real-world driver performance after a brief nap was lacking. In this respect, the efficacy of the measure was not completely proven.

The literature offers a much wider range of measures to counter chronic fatigue, because of several factors:

- the use of generic terms such as 'drowsy' and 'sleepy' for all types of fatigue
- experiences of drowsiness vary considerably among drivers
- driver resistance to stopping for a rest requires that other measures be deployed.

As noted above, some measures are also deployed whether they are effective or not.

The chronic fatigue research generally suggests that 1–10 percent of accidents arise from 'drowsy' or 'sleepy' driving, but reports suggest a range from about 20 percent in the UK (Horne et al 2001) to as much as 33 percent in Australia (Connor et al 2002, citing Pierce 1999).

In the US, the *100-car naturalistic driving study*[1] (Dingus et al 2006) provided data based on naturalistic observation, rather than self-reports or accident site analyses. The study suggested that chronic fatigue increased the risk of accidents (odds ratio of 2.9, the equivalent of driving at excessive speed), and higher-risk drivers were much more likely to drive while chronically fatigued. Further analysis suggested chronic fatigue was a factor in about 12.5 percent of crashes and near-crashes, compared to a fatigued-driver baseline of about 4.3 percent of all drivers. MacLean et al (2003) argued from a 20 percent figure (for chronic fatigue-related accidents) that most prevention efforts focused on short-term behavioural solutions and masked the underlying cultural/lifestyle problem of chronic fatigue/sleepiness. They favoured educating drivers about proper sleep habits and avoiding circadian performance lows, and argued for a strong role for health professionals in managing sleepy drivers.

Sagberg (1999) found chronic fatigue in 3.9 percent of drivers in Norway, and as noted in the previous section, Connor (2001a) found a similar level (3.1 percent of drivers) in New Zealand. Certainly, accident rates are much higher amongst those who continue to drive while sleep-deprived. Cummings et al (2001) found accident risks were higher for Washington State Highway drivers who felt 'drowsy' (ie literally felt they were falling asleep), for those who drove longer distances, and for those who had slept less than 12, or more than 17, of the previous 48 hours. Measures in this study that significantly reduced accident rates were:

- getting at least 9 hours sleep in the 48 hours prior to a trip
- stopping driving if drowsy/sleepy (overall)
- stopping at highway rest stops (specifically)
- shortening the driving time by sharing the driving or interrupting the trip
- drinking coffee
- turning on a radio.

[1] This remarkable study monitored 100 cars for over a year, using sophisticated surveillance technologies. During that time, the vehicles were driven nearly 2 million miles, yielding 42,300 hours of data. The 241 drivers of the vehicles were involved in 82 crashes, 761 near-crashes and 8,295 critical incidents. Nearly 80% of all crashes and 65% of all near-crashes involved driver inattention (due to distraction, fatigue, or just looking away) just prior to (ie within 3 seconds of) the crash.

These measures are obviously not mutually exclusive, and for example, the last two in-car measures (more appropriate to maintaining alertness and counteracting acute fatigue) may be effective supports for other measures, but are not effective against chronic fatigue in their own right.

In the New Zealand context, Gander et al (2005b) found chronic sleep restriction and any chance of falling asleep at the wheel were strong predictors of involvement in any type of accident (ie not just those identified as fatigue-related). Corfitsen (1999), among others, including McConnell et al (2003), found young males were particularly at risk of chronic fatigue because of lifestyle and driving choices. Van den Berg and Landström (2006) found experiences of drowsiness, fighting sleep and falling asleep at the wheel were common amongst truck drivers. Key measures used by this group were:

- more sleep before work
- better working hours
- naps during work
- listening to the radio
- conversations
- lowering the cabin temperature.

In context, it is clear that chronic fatigue is a major problem, but is poorly distinguished from acute fatigue. This is evident in the frequent use of measures that work for acute fatigue but are entirely inappropriate for addressing chronic fatigue. For example, as noted above, drinking coffee and taking a brief roadside rest or nap may be effective against acute fatigue, but only stopping the trip and sleeping is really effective against chronic fatigue.

Some studies showed that driver knowledge of acute and chronic fatigue is typically good. Nordbakke and Sagberg (2007) found that drivers understood the various factors influencing acute/chronic fatigue while driving, and most were aware of effective measures to avoid falling asleep. In spite of this, most would still continue driving when noticing fatigue. The most common reasons for this were the shortness of the trip, pressing appointments, and the wish to arrive at a reasonable hour.

Over a series of studies in the UK, Horne et al (2001) found that drivers did not fall asleep without warning – sleep was signalled by a period where drivers felt increasingly drowsy, and the authors noted that such experiences of drowsiness could include mild euphoria and increased driver confidence. By this time, driver impairment was far worse than realised and sleep onset could occur much more quickly than imagined. In these studies, drivers reported fighting off sleep and trying to stay awake by winding down windows, turning up the radio, stretching at the wheel and so on. In these cases, the untimely use of commonplace in-vehicle measures was actually a sign of extreme fatigue. The authors noted that some drivers, after falling asleep at the wheel, forgot having used these measures and claimed they had experienced a 'sleep attack'. The authors found that a break of at least 30 minutes was effective in restoring alertness. A short nap (under 15 minutes) or two cups of coffee/two cans of energy drink (150 mg of caffeine) during this break significantly enhanced its effects, but exercise (a brisk walk) was of little use. It is not clear from this work how well these measures work if driving continues.

In conclusion, key causes, signs and measures relating to chronic fatigue are familiar to all drivers and are also unremarkable, requiring no specialised knowledge or training. The critical measure is to prevent driving when chronically fatigued. Secondary measures are to have drivers make trip plans that take chronic fatigue into account, and to behave proactively when any initial signs of fatigue are

noticed, such as stopping to nap. In this context, there is a clear hierarchy of measures that can be applied, as noted by Grunstein et al (2004).

Programmes to combat chronic fatigue may not differ in their elements from those for managing acute fatigue. However, it is clear that programmes for chronic fatigue must include preventing drivers from driving at all, which will result in interventions with a distinct structure and content.

Because the key measure is simply adequate sleep prior to driving, it may be concluded that programmes to ensure adequate sleep before driving would reduce crash rates by 1–10 percent, and possibly by more. The studies by Connor et al (2001a, 2002) suggested an appropriate New Zealand figure would be in the order of 3 percent.

However, it is not clear from the literature how practical measures for drivers in the general public might be constructed or implemented. It is also not clear how effective such programmes are likely to be among the general public.

3.4 Summary of driver fatigue problems

The following table summarises the literature on different driver fatigue problems. It is based on recent studies that combine robust design (such as controlling for confounding variables) with the clearest evidence.

As outlined in section 2, this table (and subsequent tables) relate specific fatigue problems to key measures, with evidence for success and the relative effectiveness of these measures. Such a meta-analysis was used by Styles and Imberger (2007), which in turn drew heavily on work by Cummings et al (2001).

In the context of this review, it would be ideal to compare the evidence for, and effectiveness of, a wide range of measures, using a unified set of criteria, such as impact on accident rates. This is not yet possible, as the evidence is derived from a range of study types (with differing criteria for evidence) including driver surveys, laboratory studies and accident-site studies. Further, there are a number of harm-mitigation measures that can contribute to reducing accident rates and severity (eg in-car technologies and road engineering) that are beyond the immediate scope of this study, but might contribute to both measures and evidence.

As a result, impact on accident rates is prioritised where possible and other evidence provided as available, but this summary is not intended to be exhaustive.

Table 3.1 Summary of literature on public-driver fatigue awareness and behaviour problems

Fatigue problems	Measures	Evidence of success	Relative effectiveness (in relation to in-study measures) [a]
Alertness	In-car behavioural countermeasures	Studies show low-key, enjoyable cognitive tasks can maintain alertness	• Music and trivia tasks maintain and improve alertness (Cummings et al 2001; Dibben & Williamson 2007; Oron-Gilad et al 2007) • Caffeine (150 mg) effective for 2 hours (Horne & Reyner 2001; Cummings et al 2001). Slow-release caffeine may last longer (De Valck et al 2003) • Cooling driving cab/lowering a window improves driver alertness (Landstrom 2006) • Varying speed improves driver alertness (Tejero & Chóliz 2002)
	Infrastructure/ road design	Studies show design of road infrastructure can contribute to driver alertness	• Rumble-strips help maintain alertness and can reduce accident rates by 25% (Mackie & Boss 2007)
Acute fatigue and increasing impairment	Pre-trip interventions to educate drivers about the dangers of fatigued/ impaired driving	Studies show persuasive and emotively laden calls to action can be successful in changing driver knowledge and behaviours	• Persuasive (emotively laden) media campaigns reduce crashes by 6–9% during the campaign and by about 15% afterwards (Delaney et al 2004)
	In-car behavioural measures – educate drivers to identify and counter acute fatigue and impairments early on	Studies indicate that a range of behaviours (eg winding down window, conversation, music and drinking caffeine-based drinks) can manage fatigue	• Caffeine (150mg) effective for 2 hours (Horne & Reyner 2001; Cummings et al 2001). Slow-release caffeine may extend effects (De Valck et al 2003) • Playing music (Cummings et al 2001; Dibben & Williamson 2007) • Taking a break of 30 mins or more (Horne et al 2001), but only lasts up to 25 mins (Styles & Imberger 2007) • A short nap of up to 15 mins, and caffeine with nap is better (Horne et al 2001) • Taking two or more breaks during trip (Cummings et al 2001) • Sharing the driving (Cummings et al 2001)

Fatigue problems	Measures	Evidence of success	Relative effectiveness (in relation to in-study measures) [a]
		Studies show in-car technologies can alert drivers to increasing fatigue	• In-car driver monitoring systems can effectively warn drivers, though their impacts for general-public drivers has yet to be measured (Fairclough & Winsum 2000)
		Studies show design of road infrastructure can reduce driver fatigue	• Rumble-strips can alert drivers to increasing fatigue and can reduce accident rates by 25% (Mackie & Boss 2007). • Roadside rest areas can encourage drivers to stop and rest (Govendar 2006)
Chronic fatigue	Pre-trip interventions to prevent driving while chronically fatigued, and in-trip interventions to have drivers stop and rest	Studies based on drink-driving campaigns suggest educational and emotively laden calls to action can be successful in changing knowledge and behaviours, though regulation and enforcement also play an important role	• Having an average of 12–17 hours sleep in the 48 hours before travelling (Cummings et al 2001) can reduce chronic fatigue-related accidents by about 3%.
		Studies show that only stopping and resting can combat chronic fatigue (caffeine enhances the effect of the rest)	• Using a highway rest stop without napping (Cummings et al 2001) • Sharing driving (Cummings et al 2001)

a) This column provides evidence after 2000. Absence of evidence for an intervention suggests no evidence since 2000, though there may or may not be prior evidence.

As noted, measures to address fatigue are complicated by the fact that fatigue-related driver impairment includes impaired ability to respond effectively, and any measure must contend with this issue.

Measures against driving while chronically fatigued (driving with prior sleep deprivation) focus on the task of stopping drivers until they recover, and in this sense, are relatively simple. This is essentially a 'negative' programme (aiming to stop a risky behaviour), and among the public is most likely to require targeting young people and/or males.

Comparison with drink-driving programmes helps in suggesting:

- the usefulness of fear-based approaches (where behavioural prompts are provided)
- the need to prevent seriously impaired people from getting into the driver's seat
- the likelihood that the most serious risk-takers will not respond to generic programmes.

By comparison, measures against acute fatigue can have a broader focus. They aim to maintain alertness in drivers and help them manage low-grade fatigue and initial impairment, in order to provide a buffer between safe and significantly impaired driving. Such a programme is essentially 'positive' in that it encourages skilled driving. Among the public, it may provide a basis for generic driver safety programmes (specific research is required in this regard). A key focus is to enable drivers to notice early signs of fatigue/impairment and to act appropriately on these.

The next section explores recent literature on different driver groups in more detail.

4 Target driver groups

The driver groups discussed in this section are those that appear in the literature, and reflect those identified internationally as the higher-risk groups.

4.1 Transport groups

This section explores five driver groups as identified in the literature:

1. drivers of trucks and heavy commercial transport vehicles
2. bus/coach drivers
3. other work-related drivers (such as courier and taxi drivers)
4. shift workers
5. commuters.

4.1.1 General and comparison studies

Williamson and Boufous (2007) studied the difference between work and non-work fatigue-related crashes in New South Wales. Crashes involving fatigue were more likely to result in fatality, and whether or not they were work-related, to involve higher costs, truck drivers, and alcohol or speeding. Work-related fatigue crashes tended to occur around dawn, whereas work-related non-fatigue crashes occurred in peak-hour traffic. The researchers argued that specific work-related fatigue management strategies (as opposed to general ones) were critical to managing work-related crashes.

The US report *Commercial motor vehicle/driver fatigue and alertness study* (1996) noted that commercial drivers generally worked on limited sleep, their chronic fatigue clearly linked to night-time circadian effects, and even commercial drivers were poor judges of fatigue levels. The report noted that changes in the hours-of-service regulations alone would not solve the fatigue problem. Rather, managing fatigue would require a combination of hours-of-service regulation and enforcement, education, driver-work scheduling, fatigue-management programmes, driver screening, fitness for duty, alertness-monitoring systems and additional research. In parallel, partnerships between government, industry, drivers, safety groups, the scientific community and shippers would be needed to fully manage commercial-driver fatigue. That is, holistic approaches were advocated.

4.1.2 Truck drivers

The RoSPA report (2001) noted that truck drivers were strongly linked with fatigue-related incidents. Gander et al (2006) suggested that in New Zealand, assessment of truck-driver crashes could be improved by asking questions about recent sleep patterns and experiences of fatigue. In parallel, the ACC and NZ Police have collaborated to develop a set of questions that an officer attending a heavy motor vehicle crash should use if they suspect fatigue was a contributing factor in a crash.

In their study of taxi and local-haul truck drivers, Charlton et al (2003) found that about a quarter of local-route drivers had exceeded the 11-hour driving limit, and about a third rated themselves as ‘tired’ (at about 5.3 on a 7-point scale, where 7 denotes the imminent onset of sleep). They also noted (citing their 2001 study) that:

- a third of all the drivers studied had exceeded maximum driving hours
- 50 percent of logging-stock and long-haul drivers had exceeded maximum driving hours

- a quarter of the drivers reported feeling tired
- short-haul and older drivers showed the poorest performances in psychomotor tests.

Across these studies, the authors also concluded that fatigue levels varied significantly by type of trucking (including distance and/or sector).

These figures reflect the pattern of overseas studies. A review by Philip (2005) of more than a decade's research on commercial drivers indicated that similar patterns were internationally prevalent, and two specific patterns are of interest here:

1 Commercial drivers in general appeared to be linked with sleep-related conditions such as sleep apnoea (perhaps mediated by factors such as age and gender). Philip recommended further research into links between commercial driving and apnoea.

2 Chronic sleep deprivation was associated with shifts between weekend and working-week sleep patterns among commercial drivers. This was recognised in Europe, where commercial drivers were required to have 45 hours of rest time after every six days of continuous work.

Note the requirement for a rest time is also recognised in New Zealand, although a number of issues are recognised. First, a time-based stand-down period is not sufficient to take into account the different impacts of shift patterns, time of work and other factors that drive fatigue. Second, giving workers a suitable stand-down time to recover does not demand that they sleep (and nor should it). As a result, the legislation does not currently ensure that an employee arrives at work free of fatigue, nor does it ensure that companies abide by shift patterns that are most appropriate to minimise fatigue. These are areas that may require further attention.

Morrow and Crum (2004) found fatigue factors were closely linked to narrow escapes but not crashes. The study indicated that safety practices (establishing a strong safety culture, scheduling practices, and company assistance with combating fatiguing behaviours) could offset fatigue associated with truck driving. Arboleda et al (2003) found that driver fatigue training, driver opportunity for safety input, and management commitment to safety were all integral to a strong safety culture. Fournier et al (2007) noted that driver training focused on time management and regulations but might not have prepared trainees for real-life constraints. They found that experienced drivers managed time within broader work constraints as a whole, by:

- managing psycho-physical changes over a given work period
- flexible work planning.

Integrating these management skills into training could better prepare drivers for real-life constraints and could, therefore, reduce levels of fatigue and increase safety.

Oron-Gilad et al (2007) evaluated the effectiveness of different alertness-maintaining tasks on driver performance, and found that alertness-maintaining tasks might succeed overall, with two provisos:

1. the alertness lasted only as long as the task
2. the tasks needed to be selected carefully.

The task that most enhanced driver alertness and performance was a trivia game (other tasks had neutral and opposing effects).

4.1.3 Bus/coach drivers

The RoSPA report (2001) could not identify studies on bus/coach drivers and this remains an understudied group. A combined study of bus and truck drivers by van den Berg and Landström (2006) found that

sleepiness while driving was strongly correlated with lower sleep hours and lower sleep quality before work. Age, type of work, or work experience did not influence sleepiness in the investigated group in any systematic way. Common measures against sleepiness included more sleeping hours before work, better working hours, naps during work, listening to the radio, conversation and lowering the cabin temperature.

Machin (2001) found that a coach-driver fatigue-management training programme resulted in stronger self-efficacy and motivation, strong intentions, and high levels of additional learning activity. A longer-term evaluation suggested that additional information about managing fatigue would benefit drivers more, with steps to improve communication between management and drivers.

4.1.4 Other work-related drivers

Work-related driving may represent a large proportion of overall driving, but it is not well researched. The RoSPA report (2001) noted that taxi drivers, private hire-car drivers and many others (sales people, couriers and so on) were at some risk of fatigue-related incidents. Work-related driving is known to have higher rates of fatigue-related accidents and to be associated with sleep loss before accidents (Fell and Black 1997), though fatigue in work-related driving might be mitigated by the shorter and more varied trips typical of urban environments.

Machin and De Souza (2004) found that taxi drivers' unsafe behaviour was not directly linked with the hazards they encountered while driving. Rather, unsafe behaviour was linked with risk tolerance, aggression and perceptions of management's commitment to safety. This appears consistent with the findings for truck- and bus/coach-driver workplace programmes.

As noted earlier, the study by Charlton and Bass (2003) included taxi drivers, and found about 40 percent of them had exceeded the 11-hour driving limit, with a similar figure rating themselves as 'tired'.

4.1.5 Shift workers

The RoSPA report (2001) noted that shift workers were strongly linked with fatigue-related incidents, especially when driving home from work. Connor et al (2001a) found that about 8.1 percent of Auckland drivers with one or more characteristics likely to impair alertness were shift workers.

Di Milia and Bowden (2007) noted that the increase in shift work in many urban centres has resulted in a drive-in and drive-out workforce (DIDOW) of longer-distance commuters. Driving in the early morning and longer distances were associated with higher levels of self-reported fatigue. Some 13 percent of DIDOW drivers reported falling asleep when driving to a day shift, and 23 percent following a night shift.

This review identified no recent research on measures specific to shift workers. Hours-of-service regulations addressing shift-worker driving, especially daytime driving, would appear to be one option.

4.1.6 Commuters

Commuting has been associated with higher rates of fatigue-related accidents (Fell and Black 1997). This current review identified no recent research on measures specific to commuters.

In summary, the research on the various types of commercial drivers suggest educational programmes may have an impact on work-related driving, as might any norms, rules and sanctions a workplace might be able to provide. With appropriate design, such programmes may help build positive workplace driving behaviours that could be extended to work-related commuting and fatigued driving more generally. In parallel, programmes better suited to other communities, such as churches, clubs

and community groups, might also be developed, as is the case with smoking, obesity and other harm-reduction programmes outside the transport sector.

However, transfer of learnings from commercial-driver studies to other workplace contexts would clearly require both formative and evaluative research to ensure effectiveness. In particular, it seems important to identify realistic measures and targets for such programmes.

4.2 Demographic groups

This section explores four demographic groups – the young driver, the old driver, the tourist/holiday driver and other drivers. Note that the RoSPA report (2001) does not distinguish between these non-work-related groups and it appears young drivers, in particular, are an emerging concern in the literature.

4.2.1 General studies

In the New Zealand context, Gander et al (2005b) studied a sample of drivers aged 30–60 and found that any predisposition to sleepiness at the wheel was associated with higher accident risk. Given the relatively mature sample, even here the younger age groups were over-represented in the categories of:

- sleep-related accidents when getting less sleep
- driving above-average hours per week
- being non-Maori women.

The authors noted the need for campaigns constructed to target specific demographic groups.

4.2.2 Younger drivers

Younger drivers are associated with higher accident rates. Researchers now argue that the causes are complex and only partly related to limited driving experience.

McConnell et al (2003) found that younger drivers aged 15–21 were more at risk for sleep-related motor vehicle crashes. Corfitsen (1999) found that young male drivers were aware of, and ready to accept, driving at very low levels of arousal, which suggested they were a particularly high-risk group. Smith et al (2005) found that young drivers frequently drove while at risk of crashing, both at times of predicted sleepiness (by circadian rhythm) and at times they themselves felt sleepy. Lucidi et al (2002) found that alcohol accentuated fatigue in young drivers, and nightclubbing increased fatigue disproportionately (taking into account the parallel effects of alcohol). Horne et al (2003) found that modest and legally acceptable levels of alcohol intake by young males significantly impaired their driving.

Ulleberg (2001) identified sub-groups of young drivers (using attitudinal scales) and found that low-risk sub-groups were more likely to respond positively to media safety campaigns. The high-risk sub-groups were characterised by high levels of sensation seeking and driving-related aggression, and featured a male bias. Vassallo et al (2007) also found that young drivers engaging in risky driving behaviours (including driving while fatigued) differed from control groups by temperament, behaviour problems, social competence, adjustment to school, and interpersonal relationships. A more complex view of causality is emerging to support the view that specific sub-groups require specific measures.

Hatfield et al (2005) found that most young Australian drivers reported driving while fatigued – about a quarter did so, and on a weekly basis. They found that young drivers' understanding of the risk of driving fatigued was low, and might be inaccurate because they compared it with the higher risks of

speeding and/or drink-driving. A parallel study by Grunstein et al (2004) also found that young males had the lowest knowledge about fatigue and the poorest sleep habits.

Hatfield et al (2005) noted that young drivers also underestimated personal risk (being overly optimistic) and overestimated the effect of behaviours and situations reducing fatigue risks (such as drinking coffee or driving a short distance only). In the absence of fatigue-related legislation and enforcement, the authors argued that campaigns might best focus on the perceived risks of crashing and related social censure. But they also observed that little was known about the social norms for young-driver fatigue, aside from general views on its 'irresponsibility'. The authors suggested that public education campaigns on driver fatigue in New South Wales have presented information in ways that produce denial, propagate myths of driver fatigue, and are unclear about appropriate behaviour. The authors pointed to static and upward trends in fatigue-related crashes during the campaigns. In particular, they argued that fatigue-related campaigns should specifically target young people.

In a secondary study, the authors developed and tested a pamphlet that provided fatigue-risk information with a risk-assessment tool (a 'risk ladder'), and a section debunking myths about fatigued driving. The pamphlet produced significant changes in beliefs and intended behaviours. Note the aim of the pamphlet study was to understand how to successfully educate young drivers, as a key step towards achieving behavioural outcomes. Subsequent effects on driver behaviours were not assessed and there is clearly more work to be done in this area. Other studies cited in this review more specifically explored the links between driver education and behavioural outcomes.

A number of recent evaluations have also assessed other safety programmes, including legislation, enforcement, education and media campaigns. These are noted in the final sections of this report.

Ferguson (2003) noted that graduated driver licensing (GDL) has been successful in managing a range of risks arising for younger drivers in the US, and for example, the extended learning period could reduce the per-driver crash rate by 5–32 percent. (McKnight and Peck's 2002 study put the New Zealand figure at 7 percent) Grunstein et al (2004) recommended inclusion of fatigue-related education in driver-licensing programmes, to address the high levels of ignorance about fatigue found among young drivers. Note that fatigue is now included in GDL training programmes in New Zealand (NRSC 2008) – the impacts of this have yet to be studied. It is a complex area, as risks among young drivers arise from a range of factors, found both in isolation or combination, including ignorance about fatigue, risky driving, alcohol use, seatbelt non-use, driver distraction, fatigue and vehicle choice.

GDL and other restrictions (such as night-time driving) may limit risks such as driving while fatigued, but do not remove them entirely, and some restrictions are not actually fully supported by research. Ferguson (2003) suggested that further research would be important for defining risks and appropriate measures against them. In parallel, Williams (2006) argued that the most promising programmes:

- were coordinated and community based
- were linked with strong GDL laws
- involved modern education and training techniques
- were linked with insurance discounts
- coordinated well-publicised enforcement and education campaigns featuring parents, the police and significant input from young drivers.

McKnight and Peck (2003) argued for four particular GDL elements, namely:

1. restricting young drivers to daylight hours to mitigate the effects of circadian rhythms
2. making the advance to fuller driver-license status contingent on a fault-free performance
3. extending the young driver's learning period
4. breaking driver learning into basic and advanced stages to ensure full skills for real driving.

In France, Carcaillon and Salmi (2005) found that a safety programme (combining media and enforcement) launched in 2000 to target drivers under 25 years of age reduced accident rates in both control and test groups. They noted that unrelated national road safety actions were implemented at the same time, confounding the study results, and suggested the evaluation may have taken place too soon to assess the programme's full impacts.

In the US, Whittam et al (2006) found that a media campaign on its own resulted in a 21.6 percent decrease in crashes in which 16–19-year-old drivers were at fault. But note the decrease only lasted for the period of the campaign (as compared to both baseline measures and a control), suggesting dependence on media coverage itself to build and maintain these changes. Road safety campaigns and other activities had similar levels of effectiveness when test and control samples were compared. The authors noted that since the campaign achieved significant changes in attitudes and behaviours only as long as it continued, more sustained media-based programmes were required to change social norms, and especially to entrench beliefs about the negative consequences of risky driving.

In a review of Australian, US and New Zealand road safety campaign performance data and analytic models, Tay (2003) found that campaigns decreased crash involvement by about 10 percent (both independent of, and in addition to, enforcement activities), contrary to the prevailing belief among road safety professionals.

Tay's review classified campaigns by message type and behavioural effects (crash involvement, including alcohol-related versus non-alcohol-related crashes), and modelled their impact in relation to enforcement activities, control conditions and broader socio-economic conditions.

Tay emphasised the following points:

- a campaign design should be evidence-based
- fear-based campaigns should provide specific protective actions
- campaigns should be sufficiently funded to ensure optimal media placement (and so ensure high cost effectiveness)
- content needs to be carefully considered in relation to the campaign topic
- other campaign benefits, such as shifting public norms, should also be considered, as well as behaviour change.

Tay (2005a, 2005b) added that speed and alcohol campaigns showed different relationships between variables commonly used in analytic models, indicating that different campaign topics required different and specific approaches. For example, although drunk-driving programmes have had significant individual effects, anti-speeding campaigns have been more cumulatively effective.

4.2.3 Older drivers

McCarthy (2005) pointed out that the proportion of older people in the general driver population was steadily increasing, and specific programmes were required to ensure they continued to drive in safety. Campagne et al (2004) found that overall, older drivers' driving errors increased more with fatigue than

those of younger drivers. But Philip et al (2004) found that although the response times of older drivers were slower overall, they were much less likely to degrade when fatigued. Older drivers were also more accurate in their assessment of their driving performance when fatigued.

In terms of measures to counter fatigue in older drivers, recent studies are rare. Donmez et al (2006) found that older drivers were more willing to accept and trust technologies that enhanced driver alertness (by reducing the impact of distractions). Drivers overall were more accepting of visual than auditory warnings. Note that older drivers were more trusting of either type of warning, including when the technologies failed to register risks, suggesting some over-reliance on the technology and thus (paradoxically) potential crash risks. Owsley et al (2004) found that visually impaired older people who were given generic driver safety education regulated their driving behaviours more carefully and avoided challenging situations more than control groups, but these behaviours did not result in a lower crash rate.

Current work on older drivers is evolving with greater clarity, and it already suggests some reasons for developing measures that are specific to older drivers.

4.2.4 Tourist/holiday drivers

Fell and Black (1997) found that holiday fatigue affected drivers, and thus accident rates. Our review found no recent research on measures specific to fatigue during holiday driving/tourism.

Given that accident rates are known to increase during holiday periods, this is an important area for specific research on the effectiveness of existing measures against driver fatigue, and on potential new measures.

4.2.5 Others

Fletcher et al (2005) noted other groups at high risk from sleep restriction – for example, parents of young children, and people in specific professions featuring disrupted sleep, such as doctors, emergency workers and the police. Again, these may constitute significant groups (by numbers and/or impacts of fatigue).

They noted the fatigue problems and corresponding measures would be specific to each group, but our review identified no recent research on measures specific to these groups.

4.3 Clinical/sleep disorders

In the New Zealand context, Connor et al (2001a) found the symptoms associated with sleep apnoea were present in 1.6 percent of Auckland drivers. Yee et al (2002) found that sleep disorders were common (40 percent) among drivers reporting to Wellington Hospital's emergency room after car accidents.

Marshall et al (2003) noted that the prevalence of sleep apnoea is estimated at 2 percent for women and 4 percent for men, though the prevalence may be higher among Maori and Pacific Island peoples. Undiagnosed sufferers were also likely to be a significant group. Their literature review found that continuous positive airway pressure (CPAP) was linked with reductions in driver accident risk.

In another literature review, Pandi-Perumal et al (2006) suggested sleep disorders had significant impacts on driver accident rates, but research on countermeasures (such as medication) was limited. Studies have suggested that medication had limited effects, as it depended on compliance and might be countered by other factors such as stress and fatigue. The authors argued that social awareness and

education programmes were, therefore, also critical to effective management of sleep disorders in relation to driving.

Our review identified no recent research on measures specific to clinical sleep disorders (though clinical research *per se* is beyond the scope of this study).

4.4 Summary of target driver groups

The table below summarises the literature on general-public driver fatigue for specific driver groups. Note that various commercial drivers have been included, to enable greater learning.

Table 4.1 Summary of literature on specific driver fatigue groups

Driver groups	Fatigue problems	Measures	Evidence of success	Relative effectiveness
Truck and bus/coach drivers	Chronic fatigue	Interventions such as workplace programmes, including education and skills training	Studies show workplace programmes can reduce driver experiences of fatigue	Programmes can offset risks posed by fatigue (Morrow & Crum 2004)
Other commercial drivers	Chronic fatigue	Interventions such as workplace programmes, including education and skills training	Studies show workplace programmes can reduce driver experiences of fatigue	Programmes can offset risks posed by fatigue (Morrow & Crum 2004)
Shift workers	Acute and chronic fatigue	Interventions including workplace programmes	No recent studies	No recent studies specifically on fatigue
Other work-related drivers and commuters	No recent studies	No recent studies	No recent studies	No recent studies specifically on fatigue
Youth	Chronic fatigue	Interventions including GDL, community-based programmes, education campaigns	Studies show GDL has reduced per-driver accident numbers by 7% in New Zealand. Fatigue is now part of GDL training programmes. Studies show education campaigns can reduce fatigue-related accidents during a campaign, while integrated programmes have longer-term effects.	GDL can reduce the per-driver crash rate by 5–32% (McKnight & Peck 2002). No recent studies on youth education campaigns relating to driver fatigue.

Driver groups	Fatigue problems	Measures	Evidence of success	Relative effectiveness
Elderly	No recent studies	No recent studies	No recent studies	No recent studies specifically on fatigue
Tourist and holiday drivers	No recent studies	No recent studies	No recent studies	No recent studies specifically on fatigue
Others	No recent studies	No recent studies	No recent studies	No recent studies specifically on fatigue
Sufferers of sleep disorders eg sleep apnoea	Chronic fatigue	Interventions based on clinical management/ medication	Studies show that continuous positive airway pressure (CPAP) and medication can reduce risk	Continuous positive airway pressure (CPAP) reduces crash risk (Marshall et al 2003)

Note the absence of studies that distinguish loss of alertness versus acute fatigue, and acute versus chronic fatigue as factors. This would seem important where a group of drivers (including those not in the general-public driver group) are predisposed to a particular type of fatigue.

The next section details measures against driver fatigue, covering both interventions and countermeasures.

5 Measures against driver fatigue

This section summarises interventions against driver fatigue, using the framework proposed in section 2. Definitions used in this report are based on Fletcher et al's (2005) distinction between reducing the *likelihood* of fatigue (interventions) and reducing the *consequences* of fatigue (countermeasures). This section is not exhaustive, and for example, excludes harm-mitigation measures, including ITS in-vehicle systems and road engineering.

While discussion has been used in previous sections, tables are used here to avoid excessive repetition and to highlight salient measures. A brief discussion of each table is used to cover any new information.

5.1 Interventions

As outlined in section 2, an intervention is a measure preventing driver fatigue, and so involves both actions taken before a trip to maximise pre-trip sleep/rest, and actions to minimise in-trip fatigue. An intervention recognises that driving requires constant alertness that must be actively maintained. Interventions may occur through driver behaviour (eg driver preparation) as well as in the roading environment (eg provision for rest during long trips).

Two major problems identified in the literature are:

1. prior lack of sleep, resulting in chronic fatigue
2. sleep disorders (such as sleep apnoea).

These are also the primary focus in the literature for fatigue-related interventions, which largely focused on getting chronically fatigued drivers to stop and take a rest. The table overleaf details the different interventions in relation to key fatigue problems. It covers interventions already discussed in previous sections.

The exception is the addition of regulatory interventions, such as the recently introduced New Jersey (US) law known as 'Maggie's Law', which allows prosecution of fatigued drivers who injure someone in a crash (Stutts et al 2005). The law defines fatigue as being without sleep in the 24 hours prior to the crash, and so is oriented towards chronic fatigue and to cases where serious fatigue is a major cause. Note that many US states can also prosecute fatigued drivers under reckless-driving regulations, though actual use of these laws for fatigued driving appears to be minimal. Stutts also noted that it is important to publicise the possibility of prosecution, as this in itself impacts on public awareness of the issue. The effects of 'Maggie's Law' have yet to be assessed.

Table 5.1 Different interventions in relation to key fatigue problems

Fatigue problems	Driver groups	Measures	Evidence of success	Relative effectiveness
Lack of prior sleep/ chronic fatigue	Groups associated with chronic sleep deprivation, especially truck and bus/coach drivers, shift workers, youth/ young males	**Available** • Schedule activities • Alert driver to chronic fatigue • Reduce driver resistance to not driving/stopping to rest • Take naps, combined with caffeine if possible • Stop driving completely (voluntary and involuntary options) • Use TV and print media campaigns to educate drivers about chronic fatigue and measures against it	**Available** • Studies with commercial drivers show that integrated programmes can be successful • Studies show success with behavioural interventions with public drivers to prevent driving while chronically fatigued • Studies of drink-driving campaigns suggest accident rates can be reduced during a campaign, but different sub-groups need different measures • Studies show GDL reduces injury accident rates in young drivers, and fatigue is now included in GDL training programmes	**Available** • Programmes can offset risks posed by fatigue (Morrow & Crum 2004) • Having an average of 12–17 hours sleep in the 48 hours before travelling (Cummings et al 2001) • A short nap of up to 15 mins, and caffeine with nap is better (Horne et al 2001) • Sharing driving (Cummings et al 2001) • In-car driver monitoring technologies (Fairclough & Winsum 2000) • Persuasive (emotively laden) media campaigns reduce crashes by 6–9% during a campaign and by about 15% afterwards (Delaney et al 2004)

Fatigue problems	Driver groups	Measures	Evidence of success	Relative effectiveness
Lack of prior sleep/ chronic fatigue (cont.)		**Emerging** • Prevent driving while chronically fatigued *per se* • Regulate against driving while chronically fatigued (with enforcement) • Use threat of legal, health and social consequences in media campaigns • Use anti-fatigued driving training and elements in GDL schemes	**Emerging** • Studies of in-car fatigue-detection technologies suggest driver alerting can be successful • Studies of GDL suggest interventions against chronic fatigue may be incorporated • No studies specifically on preventing chronic fatigue were identified in this review • No recent evidence of regulatory success identified by this review, though parallels with speeding and drink-driving suggest potential effects are significant	• In-car driver monitoring technologies (Fairclough & Winsum 2000)
Sleep disorders	Sufferers of sleep apnoea and other chronic disorders	• Continuous positive airway pressure (CPAP) • Medication	• Studies show CPAP and medication can reduce chronic fatigue and decrease risks while driving	• Continuous positive airway pressure (CPAP) reduces crash risk (Marshall et al 2003)

The evidence for the interventions' effectiveness is available within workplace programmes and a few chronic-fatigue programme examples. This points to the improved success rate of programmes that are locally based, or that combine careful targeting with integrated social marketing campaigns and legislation/enforcement (where possible). Emerging measures suggest that similar criteria, such as matching the measure to the target group, are important. In-car fatigue-detection technologies may find greater use as alerting devices, while GDL could potentially incorporate driver education and enforcement measures relating to chronic fatigue.

One key area of difficulty that is shared with drink-driving is preventing drivers who are already impaired (from alcohol, sleep deprivation, or both) getting into the driver's seat. This specific measure is absent from both recent research and programmes.

Legislative measures to prevent driving while chronically fatigued are few. McLean et al (2003) noted that driving-related employment regulations provided for fatigue (though non-compliance remained an unresolved issue), but discussion of private-driver fatigue regulation was in its infancy. The authors compared current beliefs with those held about drink-driving before the 1920s, and also found that people currently judged drink-driving far more harshly than driving while chronically fatigued. They argued that public awareness and knowledge was critical for driving regulatory measures, and cited the role of advocacy organisations in stimulating this awareness and arguing for stricter legislation and penalties for chronically fatigued drivers.[2]

5.2 Countermeasures

As noted earlier in section 2, a countermeasure is a measure minimising or countering driver fatigue during a trip, and can range from exercises to maintain alertness through to stopping the trip for sleep. A countermeasure may depend on the driver recognising the early signs of decreasing alertness and acting appropriately, and so may depend in part on prior interventions. Countermeasures may occur through:

- monitoring technologies that identify early warning signs
- driver behaviours (eg changing drivers)
- roading design (eg rumble strips).

The key problem identified in the literature is loss of alertness and increasing (acute) fatigue during a trip. This is often treated in the literature as the same as fatigue arising from sleep deprivation and resulting in chronic fatigue while driving. But as argued, the opportunity to encourage alertness and manage acute fatigue suggests that distinguishing between different categories of driver fatigue is merited.

The table overleaf is used to detail the different countermeasures in relation to key fatigue problems.

[2] The New Zealand driver fatigue advocacy group Akilla emphasises the need to develop both expert and public knowledge. See www.akilla.co.nz/akilla_sleep_safety_education/drowsy_driving_actionplan/

Table 5.2 Different countermeasures in relation to key fatigue problems

Fatigue problems	Driver groups	Measures	Evidence of success	Relative effectiveness [a]
Increasing weariness during travel/acute fatigue	• Groups vulnerable to acute fatigue symptoms, eg work-related drivers, holiday drivers, commuters, older drivers • Truck drivers, bus/coach drivers, shift workers and other drivers where management of acute fatigue/ increasing impairment becomes an in-trip priority	**Available** • Maintain alertness • Drink caffeine • Play music • Vary vehicle speed • Vary in-vehicle temperature • Share the driving • In-car driver fatigue detection technologies • Provide rest bays • Provide on-road alerts eg rumble strips • Provide crash safety features eg median barriers • Plan rest stops • Take rest stops (with caffeine) • Use TV and print media campaigns to educate drivers about fatigue and measures against it • Use radio and billboards to remind drivers of fatigue and to take measures against it	**Available** • Studies show each of these behavioural countermeasures can be successful if used for initial and early signs of fatigue/driver impairments • Studies also show programmes using these countermeasures can be successful	**Available** • Music and trivia tasks improve alertness (Oron-Gilad et al 2007) • Caffeine (150 mg) effective for 2 hours (Horne & Reyner 2001; Cummings et al 2001) • Playing music (Cummings et al 2001; Dibben & Williamson 2007) • A break of 30 mins or more (Horne et al 2001), but it only lasts up to 25 mins (Styles & Imberger 2007) • A short nap of up to 15 mins, better with caffeine (Horne et al 2001) • Taking two or more breaks during trip (Cummings et al 2001) • Sharing driving (Cummings et al 2001) • In-car driver monitoring systems can warn drivers effectively, though their impacts for general-public drivers has yet to be measured (Fairclough & Winsum 2000) • Rest bays every 80 km or hour of driving can reduce accident rates (Stutts 2005) • Rumble strips help maintain alertness and prevent fatigue (Govendar 2006)

Fatigue problems	Driver groups	Measures	Evidence of success	Relative effectiveness [a]
		Emerging • Regulate against driving while chronically fatigued (with enforcement) • Use threat of legal, health and social consequences in media campaigns	**Emerging** • Studies of campaigns against excessive speed and drink-driving suggest fear-based campaigns could also work against driver fatigue, if messages include positive countermeasures	**Emerging** • Persuasive, emotively laden media campaigns reduce crashes by 6–9% during a campaign and by about 15% afterwards (Delaney et al 2004) • No recent studies specifically on fatigue • Threat of consequences effective if preventative actions are clearly specified (Tay 2005a)

a) This column provides evidence after 2000. Absence of evidence for an intervention suggests no evidence since 2000, though there may, or may not, be prior evidence.

6 Preventing general-public driver fatigue in New Zealand

This section outlines key driver fatigue strategies, measures, programme elements and research topics relevant in the New Zealand context.

6.1 Key measures

It is difficult to identify key measures independent of the type of fatigue and/or the target group, and without reference to the specific requirements of a best-practice programme. One approach is to frame key measures within two broad, complementary programmes, as outlined below.

These programmes are constructed from the recommendations of social change studies (see sections 3.2.5 and 3.2.6) and from the design of programmes framing successful measures cited throughout this report.

6.1.1 'Positive' programmes

These maintain alertness and manage acute fatigue, and aim to encourage enhanced driver skills and attentiveness to driving. This sits well with driver education and also lends itself to a variety of in-trip countermeasures. This is a relatively generic strategy, applicable across most driver groups and/or fatigued-driving situations such as holiday trips, long-distance commuting and so on. While this approach suits countermeasures (such as radio and roadside reminders to stay alert and rest regularly), a fuller programme would also require well-communicated interventions (such as the knowledge, behavioural cues and infrastructure to support frequent rest stops). Specific measures supported by the literature are:

- music and trivia tasks to maintain and improve alertness (Cummings et al 2001; Dibben and Williamson 2007; Oron-Gilad et al 2007)
- caffeine (150 mg) – effective for 2 hours (Horne and Reyner 2001; Cummings et al 2001); slow-release caffeine may last longer (De Valck et al 2003)
- cooling the driving cab/lowering a window (Landstrom 2006)
- varying the car speed (Tejero and Chóliz 2002)
- rumble strips to help maintain alertness (Govendar 2006)
- persuasive, emotively laden media campaigns – reduce crashes by about 6–9 percent during the campaign and by about 15 percent afterwards (Delaney et al 2004)
- taking a break of 30 minutes or more (Horne et al 2001) – but the effects of this only last up to 25 minutes (Styles and Imberger 2007)
- taking a short nap of up to 15 minutes – including caffeine with a nap is better (Horne et al 2001)
- taking 2 or more breaks during the trip (Cummings et al 2001)
- sharing the driving (Cummings et al 2001)
- in-car driver monitoring systems to warn drivers – these are effective, but their impact for general-public drivers has yet to be measured (Fairclough and Winsum 2000).

6.1.2 'Negative' programmes

These target chronic fatigue and aim to stop chronically fatigued drivers from driving until sleep deprivation and other issues have been addressed. This sits well with measures to stop or minimise chronically fatigued driving, and necessarily targets higher-risk groups (such as youth/young males and commercial drivers). It may be linked to GDL and workplace programmes with developments in driver legislation/enforcement. It is, therefore, a more targeted and specific strategy, deploying in-trip countermeasures as a last and/or practical resort where drivers continue to drive while sleep deprived.

Cummings et al (2001) suggested the following strategies:

- having an average of 12–17 hours sleep in the 48 hours before travelling (would reduce chronic fatigue-related accidents in New Zealand by about 3 percent)
- using a highway rest stop without napping
- sharing the driving.

These are initial strategies only and should be further developed to suit specific programmes/ campaigns.

6.2 Best-practice guide for programmes against fatigued driving

In recent years, a number of researchers have reviewed the road safety literature and have suggested generic elements for a best-practice framework for programmes against general-public driver fatigue. As many of these elements are derived from programmes for speeding, drink-driving and seatbelt use, they may need to be refined for use specifically in driver fatigue programmes.

6.2.1 Delaney et al (2004)

Delaney et al suggested that key features in the design of successful campaigns were:

- a central theory of behaviour change to focus programmes on key influences on beliefs and behaviours
- clearly identifying a central problem – the target (problem) behaviour
- clearly identifying a target audience.

They identified four elements of a best-practice approach:

1. using explicit theoretical models and research to focus programme design
2. providing strong, emotive messages with linked behaviours (to gain benefits and/or escape negative consequences)
3. using broadly based publicity/public relations/editorial to support any programme (ie unpaid media activity), if possible in combination with enforcement
4. providing multiple measures – not relying on short-term, ad hoc or 'silver bullet' programmes to effect change.

The authors noted the need to also develop appropriate success indicators. They found the social change literature featured a debate over whether attitudes change before behaviour, or vice versa, and there was evidence for both (in different contexts). However, awareness generally changed more

rapidly than behaviour, and so programme elements needed to be developed carefully with appropriate success indicators. This was especially important where the ultimate target was behavioural change.

6.2.2 Tay (2003, 2005a)

Tay made five suggestions about best practice in these programmes:

1. Decisions about message content should be evidence based, including (though not restricted to) input from the target audience.
2. Any fear-based messages should be paired with actions people can take to protect themselves, and should take account of higher levels of rejection among some groups (due to emotional rejection or blaming of others).
3. Programmes should be funded and professionally managed (as opposed to 'free' public service campaigns) to ensure high production quality and to achieve the higher benefits (relative to costs) of such programmes (noting that high production costs did not guarantee success).
4. Campaigns should not assume that messages emphasising legal consequences would be more successful than those emphasising social or health consequences (there was no evidence to say that one set of consequences was more effective than another). Having said this, regulation and enforcement would provide significant effects in their own right, as well as another set of consequences to base programmes on.
5. The effects of well-designed campaigns were significant, both directly and indirectly.

6.2.3 Haworth (2003)

Haworth noted that different media have different roles. For example, TV and print-media interventions were useful for education/altering beliefs and norms over a period of time, whereas radio and roadside billboards (and in-car stickers) were useful for reminding drivers of fatigue issues and prompting immediate counter-behaviours. Other programme elements found to be successful were:

- working in combination with community, interest group and individual activities (such as schools and workplaces)
- coordination with other services to encourage initial behaviours (such as hotlines for initial information) and to support established behaviours (such as brochures in cafes, petrol stations, roadside cafes, information centres)
- coordination with websites to provide support materials – these needed to be relevant to people who were new to the issue, right through to those who were more experienced.

All of the above elements may be combined in different ways to address different driver fatigue problems/target groups, as outlined in the next section.

6.3 Key research topics

The previous sections suggest there is now a substantial body of knowledge and evidence-based practice to support the design of driver fatigue programmes. As noted, these are based on speed, drink-driving and seatbelt programmes. By comparison, there is little specific work on driver fatigue programmes.

Further research is required in New Zealand to identify:

1. *the scale and impacts of different types of fatigue* (such as acute versus chronic) in relation to driving performance and crash risk – these need to be defined in practical ways and researched to identify strategic priorities for the smaller high-risk groups (eg young male drivers) and the larger, lower-risk groups (eg general public)
2. *an appropriate theoretical basis for programmes* seeking significant social/behavioural change – this is important to focus any programme through clear strategic thinking, efficient practices and clear outputs/outcomes
3. *the specific fatigue problems and dynamics of target groups* such as employees/commuters, youth (young males especially) and holidaymakers/tourists, especially groups that currently fall outside driver hours regulations – aiming to identify what measures match a given target group's problems, how to communicate effectively with the target group about their problems and appropriate measures, and so how to construct an appropriate programme
4. *the design of programmes to act against driver fatigue* – drink-driving appears to be similar enough to driver fatigue to act as a template, but derived driver fatigue programmes need to be constructed with care (any similarities must not be taken for granted)
5. *avenues for developing driver fatigue regulation and enforcement* – this is both problematic and an area of focus worldwide, and current approaches are exploring parallels with driver intoxication to set standards and to help communicate the levels and effects of driver impairment.

In conclusion, research supporting the design of effective driver fatigue programmes is a specific need in the New Zealand context.

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