Engineering responses to fatigue

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Abstract

The poor road safety situation in rural and remote areas has been previously identified by Austroads and other bodies as a key area that provides the potential for substantial road safety gains. Austroads initiated a major piece of research that identified fatigue as a major contributing factor to rural and remote crashes, and recommended that research be undertaken to address this issue. The current study had the following aims:

- identify road engineering based measures that may be effective in reducing the incidence of fatigue related crashes in rural and remote areas
- provide an analysis of likely engineering based treatments to combat fatigue, make an assessment on the effectiveness of these measures and identify gaps in knowledge
- identify the most promising types of locations to implement such treatments
- through discussions with jurisdictions, identify the most promising techniques and possible locations for trials

Perhaps one of the most significant issues to emerge from this study is the emergence of a strong hypothesis that the fatigue-related crash risk varies as a function of road geometry and roadside environment. If this is correct then these parameters should be taken into account when locating treatments.

The study identified six major categories of treatments likely to be useful as fatigue countermeasures: rest areas, monotony reduction treatments, perceptual treatments, signage and road markings, audio-tactile treatments and barriers and clear zones. Some novel ways of combining specific treatments, that may be particularly effective as a fatigue countermeasure, are suggested.

Keywords

Driver fatigue, Road Engineering treatments, Rural road safety

Introduction

The poor road safety situation in rural and remote areas has been previously identified by Austroads and other bodies as a key area that provides the potential for substantial road safety gains. Crash data reveals that about half of road fatalities across Australia occur in rural and remote areas. While road safety strategies have delivered substantial gains in crash reductions in urban areas, in general these gains have not been matched in rural and remote environments.

To gain greater understanding of the extent, trends and factors surrounding road trauma in rural and remote areas, Austroads initiated a major piece of research. Amongst the findings, this study identified fatigue as a major contributing factor to rural and remote crashes, and recommended that research be undertaken to address this issue. For example, New South Wales research shows that fatigue is involved in 18% of crashes (New South Wales Department of Transport, 1998) and Ryan et al., (1998)[1] reported that 19% of country drivers in the north of Western Australia said that they had fallen asleep at the wheel at least once. According to the Office of Road Safety in Western Australia fatigue could be responsible for up to 30% of fatalities.

However, fatigue is not simply falling asleep at the wheel. It includes, and results in, drowsiness, loss of alertness, bad mood, impaired reaction time, impaired decision making capacity and memory problems. All of these can have a significant impact on driving performance and crash risk.

In addition, it is important to distinguish between two types of fatigue: active fatigue and passive fatigue (Desmond and Hancock, 2001)[2]. Active fatigue is the result of prolonged effortful mental and physical tasks such as driving on a busy or demanding road. Passive fatigue in contrast is elicited by monotony.

There are a number of engineering based approaches that can be taken to address this problem, and the purpose of this project was to identify these measures, identify the effectiveness of them, and to provide information to practitioners about where they might be used.

The objectives of the study were to:

- Gain a greater understanding of road safety engineering based measures that can be used to address fatigue in rural and remote regions
- Identify or estimate the effectiveness of these measures
- Identify where these measures could most effectively be used
- Identify future research needs on this topic, including the need for trials of the most promising measures.

The definition of 'engineering based measures' in the current context is perhaps broader than the traditional notion of road engineering treatments. Essentially the meaning utilised here includes any change to the road or road environment. In addition, it should be noted that this report does not cover behavioural or in-vehicle countermeasures. A useful reference for readers interested in these areas is the recent Austroads report, Road Safety in Rural and Remote Areas of Australia (Austroads, 2005)[3].

Methods

The study comprised the following tasks:

- Literature and internet search to identify road engineering based measures that may be effective in reducing the incidence of fatigue related crashes in rural and remote areas (e.g. audio-tactile edgelines, rest areas, signs etc).
- Contact with local and overseas experts
- An analysis of likely engineering based treatments to combat fatigue. Assessment of the effectiveness of these measures, and identification of gaps in knowledge.
- Identification of the most promising types of locations to implement such treatments. Identification of possible locations for trials of the most promising techniques. Identification of future research needs, including current gaps in knowledge and the best ways to address these.

The research method included extensive desktop research, including internet, library and database searches to locate all relevant material.

The potential engineering treatments were examined in detail, along with other relevant issues identified in the course of the literature searches.

Consultation with experts also formed part of this phase of the project. This consultation was by means of face to face meetings for some Australian experts and via phone and email, while those with overseas experts occurred largely via email. Attempts were made to obtain relevant information from the USA, UK and Sweden, where it was believed there could be information of interest.

Greater detail on the methodology, including the consultation process can be found in the primary report (Austroads, 2008[4]).

Results

Types of countermeasures

The total range of road engineering countermeasures identified as potentially relevant to fatigue were categorised into six major categories:

1. Provision of opportunities to rest, and encouragement to do so (e.g. rest areas, advice on next rest area, town etc)

2. Ways of letting drivers know that they should rest (e.g. reminders to rest after a certain period of time driving, perceptual tests that help drivers identify their fatigue)

3. Things that reduce monotony (e.g. signs, art, cognitive exercises)

4. Alerting drivers to specific hazards, and help avoiding departure from the roadway (e.g. standard warning signs and markings, high reflectivity signs and markings)

5. Treatments alerting drivers to their departure from the roadway (eg audio-tactile edge lines)

6. Protection for drivers if they do depart (eg barriers, clear zones, providing a forgiving roadside).

Placement of countermeasures

Information was also sought on priority locations where fatigue-related crashes are likely to occur, and therefore the highest priority locations to treat.

There are two methods available with which to determine high priority locations for treatment of fatigue related crashes. The traditional approach to road safety has relied upon crash history. New Zealand and some Australian states record details of contributory factors to road crashes, including whether fatigue was thought to be involved. Where such information exists it is possible to analyse and plot this information to determine high risk lengths of road. There are some issues relating to the reliability of such data as it typically involves the subjective assessment of the police as to whether a motorist was fatigued. Also, in a number of Australian jurisdictions, there is no information on contributory factors. Instead, proxy measures of fatigue may be used. In addition, some jurisdictions utilise both approaches. Diamantopoulou et al. (2003)[5] reviewed a number of studies that identified crash based definitions for fatigue, although they noted marked differences between these. Dobbie (2002)[6] also reviewed commonly used definitions of fatigue from around Australia and overseas. That work led to surrogate measures of fatigue, with a crash selection method as follows:

First,

- exclude all crashes where the driver had a blood alcohol concentration (BAC) greater than 0.05g/100ml
- exclude all crashes involving any unlicensed drivers or unlicensed motorcycle riders
- exclude all crashes involving a pedestrian
- exclude all crashes where the speed limit is less than 80km/h

Then,

- include all head-on crashes where the vehicle was not overtaking at the time
- include all single vehicle crashes that occurred between midnight and 6am, and between 2pm and 4pm

There are likely to be a number of flaws in the definition of fatigue proposed by Dobbie. There appears to be no basis to excluding crashes where the speed limit was less than 80 km/h (indeed, a quick analysis of New Zealand casualty crash data shows that around a third of crashes recorded by police as involving fatigue occurred at locations with lower speed limits). This and other exclusions would appear to make the surrogate measures conservative (under-estimating the true extent of fatigue related crashes). Further work is required to identify a commonly accepted crash based definition for fatigue crashes, although existing information forms a useful starting point in the identification of routes or areas where fatigue is likely to be a problem.

The second method for identifying sites for treatment is also based on existing knowledge of where fatigue crashes occur. However, rather than identify specific locations, this approach identifies environment types where such crashes are likely to occur. In a recent naturalistic study, Smith, Oppenhuis and Koorey (2006)[7] mapped the distribution of fatigue related crashes in New Zealand according to the terrain surrounding the crash environment. They defined the crash sites as either high attentional demand (e.g. winding, hilly roads), low attentional demand (e.g. flat straight roads) or transitional areas (e.g. moving from previous high attentional demand to low attentional demand area). They found that crashes were much more likely to occur at locations of low demand or transitional demand (high to low).

According to Smith et al. (2006), in the case of low attentional demand areas this is likely the result of fatigue induced via monotony, and in the case of transitional areas, the result of the performance decrement that might accrue from the subconscious relaxation that occurs as workload suddenly decreases.

A related phenomenon that might explain the findings of Smith et al. (2006) has been reported by Oron-Gilad and Hancock (2005)[8]. They found that while fatigued drivers demonstrated a general driving performance decrement, this decrement was manifested differently for different kinds of roads. In particular, on a straight road the performance decrement manifested as a reduction in lane positioning and steering wheel control. However, on a winding road the performance decrement manifested as a reduction in speed control, with speed increasing as the journey progressed.

Oron-Gilad and Hancock explain these results in terms of the allocation of a limited pool of resources that results from fatigue combined with a prioritization strategy. Essentially, the fatigued driver allocates the limited attentional resources available to keeping the most important aspect of the driving task at an acceptable level of performance and devotes less attention to the least important aspect, resulting in a corresponding decrement in performance for that aspect. Thus, on a straight road the driver does not have to pay attention to lane position continuously and so it is that aspect that suffers rather than speed regulation. On the other hand, when on a winding road, attention to lane position is relatively more important and so it is speed regulation that suffers. The result of this is that the fatigued driver is more likely to approach a bend too fast on a winding road and track poorly on a straight road. Both of these scenarios are plausible antecedents to the crashes that typify rural and fatigue related crashes .

In order to mitigate against crashes with these antecedents one could speculate that it may be important to concentrate countermeasures along straight monotonous roads and on winding, demanding roads, particularly in locations immediately preceding a transition to a straight monotonous road. This approach coupled with an analysis of existing fatigue crash locations would provide a useful starting point in the prioritisation of sites to treat in order to reduce fatigue related crashes. The idea that geometry may be an important factor in rural and fatigue related cashes is not new of course and road authorities have been conducting roads, which could have been straight, with curvilinear alignment for precisely this reason for many years.

Gaps in knowledge

Locational research
Perhaps one of the most significant issues to emerge from this review is the emergence of a strong hypothesis that the fatigue-related crash risk varies as a function of road geometry and roadside environment. Specifically, that the fatigue-related crash risk is higher on monotonous sections of road and those sections of road where there is a transition from demanding to undemanding geometry.

If this is correct then these aspects of geometry and roadside environment should be taken into account when locating treatments. However, as noted above, the geometry-dependent crash cluster results discussed in this paper are based on New Zealand data and may not translate into an Australian context. For this reason it is imperative to investigate whether these results hold for Australian jurisdictions.

Therefore, it is suggested that an in-depth study of the crash databases in Australia be conducted where all suspected fatigue-related crashes are mapped, with a view to replicating the geometry-based findings of Smith et al. States with the most significant fatigue-related crash problem would be targeted; that is, Western Australia, Queensland and South Australia.

Rest areas
A major gap in knowledge surrounds the effectiveness and most beneficial placement of rest areas. While the National Guidelines for the Provision of Rest Area Facilities (NTC, 2005)[9] provide guidelines for the spacing of rest areas, they do not take into account the road geometry issues noted above, or previous fatigue related crash history. For this reason research into whether rest areas can be a more effective fatigue countermeasure if located according to additional road geometry criteria is required.

In addition, there are major gaps in our knowledge regarding the optimal nature of rest area facilities generally, as well as the kinds of features and facilities that encourage rest area usage, the optimum signing regime for rest areas and the issues surrounding providing time to destination signage. For this reason further research in these areas is clearly warranted.

Monotony reduction
While the research to date appears to provide a reasonable degree of certainty that monotony reduction can be helpful in reducing fatigue-related crashes, it does not specify what kinds of treatments count as necessary and sufficient for a worthwhile effect. It may be that something as simple as roadside 'art' or signage may be sufficient to break monotony and reallocate attention to driving enough to provide a significant fatigue countermeasure.

For this reason a research project that investigated the impact of such installations would be very worthwhile. Signage and roadside art could be tested by way of simulation, or would be relatively economical to install and could be placed at critical locations predicted to be high risk areas, as per the geometry considerations discussed above.

Perceptual treatments
While there has been some research into the effectiveness of perceptual countermeasures, this has not been from the perspective of fatigue. In addition, the idea of using a perceptual test or 'alerting' scenario appears not to have been canvassed in the literature at all. Thus the whole area of perceptual treatments as fatigue countermeasures remains a major gap in knowledge and thus worthy of research attention.

Signage and road markings
It has often been suggested that fixed signs that indicate that a particular stretch of road has a significant fatigue related crash risk may be useful. However, there appears to be no research investigating the impact of fatigue warning signs specifically.

While Variable message signs have been extensively utilised and evaluated in recent years this has not been as a fatigue countermeasure. This is a major gap in knowledge as there is obviously substantial potential for variable message signs to be used in this way. Correctly designed, these may serve multiple functions; for example, warning of a fatigue risk on that section of the road, reducing monotony in addition to conveying information about specific hazards or road conditions.

Audio-tactile treatments

There are a considerable number of evaluations showing that audio-tactile *edgelining* can be an effective fatigue countermeasure. However, while at least one study has evaluated the impact of *transverse* audio-tactile treatments from a fatigue perspective there appears to be no reference to any field evaluations of such treatments specifically as a fatigue countermeasure.

If it is correct that fatigue-related run-off-road crashes are more likely to occur on long straight sections of road and areas of transitional geometry (winding to straight), as discussed above, then there would be merit in installing and evaluating such a treatment at sites with these geometric characteristics.

Barriers and clear zones

While there is considerable research demonstrating the value of barriers and clear zones, future research and evaluation aimed at utilising these treatments as a fatigue countermeasure should investigate installations on straight monotonous sections of road and on areas of transitional geometry (winding to straight).

Discussion

While many of the treatments investigated have been utilised in most jurisdictions in Australia for some time, many may not have been applied and located in a way that maximises their effectiveness as fatigue countermeasures. Specifically, it appears unlikely that consideration has been given to concentrating these treatments in locations where monotonous, and transitions from demanding to undemanding driving environments occur. For this reason, it is suggested that as an additional consideration when locating these treatments that the issue of road geometry be considered. This would lead to a greater concentration of such treatments along straight (monotonous) roads, and immediately preceding a transition from a winding (demanding) to a straight (undemanding) road.

However, a necessary first step would be to attempt to replicate these results in an Australian context. This is important because the geometry-dependent crash cluster results referred to in this paper are based on New Zealand data and may not translate into an Australian context.

In addition there are a number of ‘new’ treatments which may be valuable and could quite easily be trialed and evaluated as fatigue countermeasures:

- Perceptual effects/tests/cognitive engagement to provide fatigue level feedback and to encourage alertness
- Improved signing for rest opportunities (e.g. time based)
- Anti-monotony roadside design (roadside art, landscaping) to provide mental stimulation
- Warning signs and road markings to aid understanding of the driving environment
- Vehicle activated and variable message signs to provide warnings without habituation
- Perceptual treatments to create the illusion of more demanding geometry
- Transverse audio-tactile treatments as an alerting device

While it would be worthwhile to evaluate the impact of any, or all of these countermeasures, the risks associated with particular geometries suggest that a key component of any fatigue countermeasure will involve warning the driver of the start of a high risk section of road, based on its geometry. Perhaps the most economical way of alerting drivers to the increased fatigue risk at the start, or ‘gateway’ to a high risk section of road would be to provide a fixed sign indicating the high risk status of the next section of road. However, it may also be valuable to literally 'alert' drivers by simultaneously providing an audio tactile signal from transverse rumble strips.

In addition, for undemanding, monotonous sections of road the challenge is to keep drivers alert for the duration of their journey along that section of road. While vehicle activated and variable message signs and anti-monotony roadside design would be excellent ways of attempting to promote driver alertness, they are undoubtedly expensive treatments. One relatively economical way to promote driver alertness would be to provide some kind of perceptual test for drivers so that they can more accurately evaluate their own level of fatigue. Roughly, the idea would be to provide some kind of perceptual event (e.g. a sign or road marking) shortly followed by a sign asking drivers to recollect the perceptual event. For example, the perceptual event might be painted transverse bars on the road and the sign (or signs) might say "Did you see those lines on the road?", "If not you need to rest now". Alternatively, the lines could be transverse rumble strips and the question could be "Did you see those lines before you felt them?" This kind of approach not only provides fatigued drivers with feedback about their fatigue level, it also has the effect of engaging non fatigued drivers, thus helping to prevent the onset of fatigue.

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