National Heavy Vehicle Regulator

Risk Classification System for Advanced Fatigue Management Evidence Statement

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1 Scope

The aim of this paper is to provide an evidence base to support the proposed template categories put forward as part of the Independent Expert Panel on Heavy Vehicle Policy final report.

The paper summarises the currently available evidence from the scientific literature for each of the seven principles on which the templates are based. For each principle, the available evidence is summarised then this is used to explain the rationale for each of the risk-based categories suggested in the template.

It is important to recognise that while the scientific evidence identifies each of these principles as important, evidence on the specific details to establish limits in the templates is limited at best.

For this reason, the templates have been based on a minimalist approach of low, medium and high risk that is based as far as possible on scientific research findings in combination with pragmatic considerations. The template limits can be easily modified as new, relevant evidence becomes available.

2 Overview

The design of the proposed scheme is consistent with long-term trends in safety regulation both in Australia and internationally and for a range of hazards including but not limited to fatigue.

The use of risk-based approaches to safety regulation have a long history beginning with the Robins report in the UK (1972) where the benefits of performance based regulatory models were first articulated as a regulatory principle.

These changes were reflected in the changes to Australian OHS laws beginning in the mid 80's and have continued ever since. The ubiquity of risk-based approaches is acknowledged implicitly thorough the evolution of the Australian standard for risk management (AS 4360) which has formed the basis of the recent ISO standard for risk management (ISO 31000).

With respect to fatigue, risk-based approaches are currently advocated in the US, UK and Canada as well as Australia and NZ. These approaches have emerged in the transport sector for rail and aviation modes and more recently in road transport.

Within Australia, the current fatigue regulations for road transport already use an implicit model of risk-based regulation through the 3-tiers of standard, basic and advanced fatigue management.

The current regulations are, in effect, a transitional stage between a traditional prescriptive model and the proposed approach which presents a model that is explicitly risk-based and more tightly aligned with the Australian and ISO standards.

The current proposal represents a logical extension of the longer-term trends however as an extension of existing regulatory policy, it is not possible to provide definitive evidence that this approach has been trialled and evaluated for road transport. However, the scheme has been based on research and analysis and this is presented in the outline of the seven principles.

The framework has been based on three clear dimensions:

1. **Work Related Rest Breaks** : breaks from driving within work opportunity (WO) to reduce performance impairment due to extended time-on-task
2. **Recovery breaks:** sleep opportunities between work opportunities (WO's) to provide enough time to obtain sufficient sleep in order to reduce the likelihood of unsafe levels of fatigue
3. **Reset breaks:** breaks in sequences of WO to reduce the likelihood of the build-up of unsafe levels of fatigue over an extended sequence of shifts

These three dimensions have been further subdivided into a set of seven principles or sub-dimensions that enable an operator to undertake a risk-assessment of the working time arrangement and to determine, where appropriate, the level of risk mitigation required in order to undertake the pattern of work safely. The seven principles are:

Work-related Rest Breaks

1. Reduce the time spent continuously working in the work opportunity
2. The more frequent breaks from driving the better

Recovery Breaks

3. Provide an adequate sleep opportunity in order to obtain sufficient sleep
4. Maximise night sleep
5. Minimise shifts ending between 00:00 and 06:00
6. Minimise extended shifts

Reset Breaks

7. Reduce the accumulation of fatigue with Reset breaks at least 30 hours and including two night periods (00:00-06:00) between work sequences

The template and its seven principles is designed to accommodate the need for working and resting hours practices that are recognised to produce high fatigue risk on some of the principles by ensuring that drivers are not experiencing fatigue due practices that create fatigue risk on other principles.

An essential element of the risk template approach is that the seven principles interact. By defining levels of risk, it is possible to allow a schedule that involves combinations of high to medium risk, but to ensure that these higher risk elements are balanced by elements that comply with low risk for other principles. The limits that have been set in the template have been set based on both science and pragmatic operational considerations.

2.1 Principles 1 and 2.

1. Reduce the time spent continuously working in the work opportunity
2. The more frequent breaks from driving the better

2.2 Evidence

The scientific evidence that fatigue worsens with longer working times is convincing (see Principle 6), but the extent to which rest breaks within work reduce this, and the most effective duration and frequency of rest breaks within work is less clear.

The available evidence is drawn mainly from industrial and laboratory studies and from a few on road trucking studies of shorter trips. This provides good evidence to support the value of frequent short breaks but that the benefit of these breaks is partial and temporary depending on how long into the trip they are taken.

No studies have been found that look at the effect of breaks over long work shift over 11 hours as most of the research on work-related breaks for truck drivers was conducted mainly in the USA where working hour limits are less than for Australian truck drivers.

Evidence from industrial studies have shown that the increasing accident and injury risk with increasing time on task can be reduced by taking regular rest breaks during work time. Large scale studies of Injury and accident risk show that risk decreases immediately following a rest break, but then begins to increase within the next 30 to 60 minutes, until the next rest break (Folkard and Lombardi, 2006; Tucker, et al., 2006).

There are few studies of the effects of rest breaks from driving. Some evidence comes from a study of Australian taxi drivers that found that the total time in rest breaks was associated with fewer accidents, although none of the accidents was reported as directly related to fatigue (Dalziel and Job, 1997).

Another study of mini bus drivers in the Middle East also showed a relationship between few rest breaks and higher accident rates (Hamad, Jaradat and Easa, 1998). A survey of Argentinean freelance truck drivers found that crashes were significantly lower for drivers who took a 30 to 40 minute break from driving (Perez-Chada et al. 2005).

Currently the most direct evidence on the relationship between breaks during work and accidents comes from a study of 96 US truck drivers whose trucks were instrumented for four weeks (Blanco et al, 2011).

This study found that a 30 minute rest break reduced the number of safety critical events (crashes, near crashes and unsafe events) by 28 percent in the hour following the rest break compared to the hour before.

In combination, these studies highlight the need for rest breaks during work as a means of reducing the risk of accidents. There is less evidence however on when during the work period that rest breaks should be taken or how long the break should be.

A study of simulated highway driving found substantial increases in sleepiness and poorer driving performance occurred by the end of 90 minutes of driving (Ting, et al., 2008) suggesting that rest breaks should ideally occur before that time. A study of the duration and frequency of breaks showed that short frequent breaks reduced errors compared to waiting for longer periods (Kopardekar and Mital, 1994), although this was in a computer operations task, rather than driving.

A review of the evidence on the impact of rest breaks concluded that short frequent rest breaks are most beneficial especially early in a shift, and workers should be encouraged to take breaks in response to their experience of fatigue (Tucker, 2003) however the authors point out that evidence on the optimum duration and frequency of rest breaks during work is lacking.

Overall, there is little evidence available, on the length of individual rest breaks. A study of breaks during driving found that 15 minute and 60 minute breaks had similar benefits for performance (Lisper and Eriksson, 1980) although including food increased the value of breaks, no matter for how long. This study suggests that even short breaks can be worthwhile although clearly more research is needed on the most effective durations of rest breaks.

There is some evidence that breaks that include a nap are beneficial for reducing fatigue, although the effectiveness depends when the napping break is taken and the extent of sleep deprivation. A meta-analysis of the effect of naps on fatigue management (Driskell and Mullen, 2005) concluded that the benefit of naps is directly proportional to their length. A 15 minute nap produced benefits lasting two hours while a four hour nap benefited performance for 10 hours.

They also concluded that timing of naps was important as the benefits decreased with the longer time between naps, regardless of the length of the nap. A review of nap lengths showed that the shortest duration to maintain performance was four minutes and that naps longer than 20 minutes lose their benefits as they are much harder to wake from (Naitoh, 1992).

Also, there is evidence that longer naps are needed to overcome longer periods without sleep (Caldwell, et al., 2008). There is also evidence that naps taken early, before a period of work, will benefit performance Bonnet, 1991; Scheitzer, Muehlbach and Walsh, 1992).

A study of long haul truck drivers (Macci, Boulos, et al., 2002) showed that a three hour nap taken before night time driving in a simulator improved sleepiness and fatigue and produced faster reaction speeds and more consistent performance on psychomotor tasks.

Also important is when the nap is taken with respect to the circadian rhythm as this determines the ease of falling asleep.

Naps taken closer to the circadian peak will be harder to initiate and not last as long (Gillberg, 1984), but those taken at the circadian trough are harder to awake from and can have adverse effects of 'sleep inertia' on performance as a result.

2.3 Template categories

It is generally accepted that breaks during work benefit performance and safety in general but unfortunately, there has been very little research on the issue of when breaks should be taken during work.

The evidence that exists on the benefits of breaks during work has been almost entirely supportive. The scientific evidence for the timing and duration of rest breaks, however, is lacking. We have evidence of benefits from 30 minute breaks, but there has been no research on shorter durations of breaks.

As working hours regulations for long distance road transport in Australia have traditionally included minimum break times of 15 minutes, the templates have specified 15 minutes as the minimum length of break taken, but specified more frequent breaks as most ideal. Therefore a 15 minute break every two hours is classified as baseline, every three hours is classified as low risk, every four hours is medium risk and every five hours is high risk.

As the purpose of breaks from driving are not only to manage fatigue risk, but also to allow for meals and personal needs, the minimum total length of break time has been specified as 6-10 percent of total Work Opportunity (corresponding to 61 to 102 minutes required in 17 hour WO, high risk) and up to 20 percent of total Work Opportunity (204 minutes in 17 hour WO, low risk).

3 Ensure an adequate sleep opportunity in order to obtain sufficient sleep

3.1 Evidence

Studies show a strong relationship between amount of sleep obtained before starting a trip and the risk of crashing. A recent study of sleep at home and on the road in a group of Australian truck drivers showed that the average sleep length was just less than six hours (Baulk and Fletcher, 2012).

A large study of crashes in New Zealand showed markedly higher crash risk for drivers who had only had five hours or less sleep the night before their trip (Connor et al, 2002). This was confirmed by a study of crashes in the US where drivers who had 9 hours or less sleep in the previous 48 hours had an increased risk of crashing and this risk increased with decreasing amounts of prior sleep (Cummings, et al., 2001).

A study of Australian truck drivers showed that drivers reporting less than 6 hours sleep before their shift were twice as likely to experience dangerous events while driving. These studies indicate that drivers need at least 6 hours of sleep in their rest breaks between work shifts.

This evidence is also supported by research on the amount of sleep people really need. While researchers do not completely agree on the optimum amount of sleep we need to perform well and to remain healthy, they do agree that we need at least 6 hours sleep each night (Ferrara and De Gennaro, 2001).

There is evidence from an evaluation of changes to Hours of Service regulations in the US that when truck drivers were allowed two hours longer rest time between work shifts (from 8 to 10 hours), they obtained more significantly more rest (6.28h compared to 5.18h on average) (Hanowski, et al., 2007).

3.2 Template categories

Based on this evidence, long rest breaks between shifts should be at least 7 hours to allow drivers sufficient time to obtain a minimum of 6h of sleep in order to ensure their capacity to perform safely.

This is clearly only sufficient time to obtain the minimum amount of sleep. This is the reason for 7 hours being classified as high risk. A 7 hour break will, realistically, only achieve sleep of less than 6 hours which is barely adequate, especially over consecutive days. Longer rest breaks will allow for greater sleep opportunity and it is clear from the US research that drivers will use the opportunity to obtain more sleep.

In addition, the amounts of sleep time allowed should be increased if work hours have been very long or involve night work (see following section on long hours of work). If the sleep opportunity is only available during the day period, the long rest period should also be longer (see next section). The balancing of long work hours and night work with greater sleep opportunity is a critical element of the risk classification system.

4 Maximise night sleep

4.1 Evidence

There is abundant evidence that the daily body or circadian rhythm exerts a strong influence on when sleep is most likely to occur and be of best quality. Sleep is most likely at night and sleep during the day is shorter and more fragmented than sleep during night (Dijk, Duffy and Czeisler, 1992).

There is also considerable research evidence that shift workers and people who are required to work at night develop chronic partial sleep deprivation. This has been shown to adversely affect alertness and performance (Balkin, Rupp et al., 2008).

4.2 Template categories

As shown by the evidence cited above, to obtain the greatest benefits from sleep opportunities, they should occur at night. Clearly for long distance road transport, this is not always possible. For some operations, this may never be possible.

For these reasons, driver schedules that do not allow night sleep are of higher risk than those that always allow night sleep. There is no definitive evidence about the relationship between the number of night shifts in a shift schedule and crash risk.

Therefore the template has been designed to balance operational demands and fatigue risk management for drivers but taking into account the evidence that night work and day sleep result in poor fatigue management.

Consequently, the templates have been designed to count more than half of sleep opportunities occurring at night (up to 50% of nights (00:00-00:06) involving work) as medium risk and less than half of sleep opportunities occurring at night (more than 50% of nights (00:00-00:06) involving work) as high risk.

Again, where night work is required, drivers should be allowed longer rest periods and shorter work periods in order to balance the high demand of night work with greater opportunities to obtain sufficient quality rest.

5 Minimise shifts ending between 00:00 and 06:00

5.1 Evidence

Night work involves higher crash risk than day work. Studies of European truck drivers (Hamelin (1987) and US truck drivers (Lin, et al., 1993) showed higher heavy vehicle crash risk at night.

Even more relevant, studies of US truck driver crashes showed that the peak crash risk for truck drivers in fatigue-related crashes was 00:00 to 06:00 hours (Kim, 2001) and that the odds of crashing for heavy vehicles is doubled during this period (Hertz, 1986).

In addition there is a multitude of studies that have shown performance in general is poorer during the night period compared to the day period, especially during 00:00 to 06:00 hours. The worst performance decrements are found in the period of circadian low (00:00-06:00h) (Barger, et al., 2009).

In situations where the end of a work period coincides with the 00:00 to 06:00h period, the problem is even greater. Drivers doing night work who are tired due to the time already worked who then encounter the circadian low point produce lowest alertness and performance and are at significantly higher crash risk.

Kecklund and Akerstedt (1993), for example, studied sleepiness and driving performance of truck drivers and found that night driving involved greater sleepiness and clear signs that drivers doing 11 hour trips were entering the early stages of sleep during the last two hours of driving (between 04:00 and 0600h on average).

5.2 Template categories

Based on these studies, there are limits on the night hours worked and the number of nights worked in each seven or 14 day period. Again, the templates are based on pragmatically balancing operational needs and fatigue risk management.

Although the evidence is strong that the combined effect of a long period without sleep and the circadian low period produces highest crash risk, there is only general guidance from the research on how crash risk changes with the number of times this combined effect occurs in a shift.

Consequently, the templates regard low risk as schedules that do not require any work opportunities to end in the 00:00-06:00h period. Schedules that include up to half of work opportunities ending in the 00:00-06:00h period are viewed as medium risk and those with more than half of work opportunities ending in this period are counted as high risk.

6 Minimise extended shifts

6.1 Evidence

There is a large amount of research evidence from truck drivers and drivers in general, that crash risk increases with increasing hours of time at the wheel. Hamelin (1987) showed that for French truck drivers, risk rate of crashes doubled for work beyond 12 hours duration compared to those doing 8 hours or less.

There have been several studies of truck drivers in the US that also show a strong relationship between hours of driving and crash risk. For example, Harris and Mackie (1972) showed accident rates increased from the seventh to the tenth hour of driving when the drivers completed their trips.

Jones and Stein (1987) compared the circumstances of truck crashes with similar truck trips that did not involve a crash and also showed that crash risk increased after around 8 hours of driving. Also in the US, Lin et al (1994) found that the eighth and ninth hour of driving time were associated with increases in crash risk by 80 and 130 percent respectively compared to the fourth hour of driving.

In addition, an interview study of US truck drivers showed a doubling of the likelihood of falling asleep at the wheel for drivers who reported driving more than 11 hours often or sometimes (McCartt et al, 2008). Further, a New Zealand study of truck crashes showed that crash risk increased significantly after around 8 hours of driving following a compulsory 10 hour break (Frith, 1994).

A recent study in the US involving long distance truck drivers in instrumented trucks studied over a two week period showed a significant increase in the rates of safety critical events at the end of 11 hours of driving (Blanco, et al., 2011) although this effect was at least partly due to the influence of a few drivers who had overall higher rates of safety critical events.

More importantly, the study showed that the risk of safety critical events was significantly increased for driving at the end of the regulated maximum 14 hour work period, even when driving hours were as short as four to six hours. This reinforces the need to consider working time not just driving time.

Studies of drivers in general also show increased crash risk with longer drive time. A very well-known set of studies by Lisper and colleagues (1986) which looked at driving on a closed track found that most drivers fell asleep within 8 to 12 hours after starting a drive, despite 3 hourly short rest breaks.

In addition, Philip et al (1999) studied drivers at rest stops on a motorway in France and found that the drivers who had driven for longer before the rest stop had significantly lower reaction speed.

A number of other studies showed increased fatigue and sleepiness with increasing hours of work. For example Kecklund and Akerstedt (1993) who showed that total work hours was the best predictor of both subjective sleepiness ratings and physiological changes indicating sleepiness (electroencephalography).

The most recent national survey of Australian heavy truck drivers (AMR Interactive, 1997) also demonstrated that total hours worked in a typical week were significantly correlated with the frequency of reported fatigue and the number of fatigue-related dangerous events reported over the last 12 months.

All of these studies provide strong evidence that we need to limit the number of hours of driving and working over a 24 hour period. Most of the studies suggest that crashes become increasingly more likely with longer duration of work from around 8 hours of driving. Most of the studies only looked at driving durations up to around 12 hours and up to 14 hours of work.

If crash risk is significantly increased at around 8 hours of driving, hours beyond 8 must involve even higher levels of crash risk. This evidence suggests strongly that setting limits on Standard hours at a maximum of 12 hours of work/driving in 24 hours already involves an elevated risk of crashing.

Adding further hours of work/driving therefore could not be judged as safe without also offsetting the elevated crash risk with some strong alternative fatigue risk management strategies, especially longer and more strategically placed rest.

A study of simulated long work hours by Australian truck drivers (Williamson, Feyer et al., 2000) demonstrated that rested drivers could maintain performance on a set of laboratory tests related to the task of driving (reaction time and attention) over a 16 hour work day (including breaks) beginning around 08:00 hours but with only a six hour break, performance deteriorated very rapidly during the next work shift.

These findings suggest that long work opportunities of 15 or 16 hours would need significantly increased sleep opportunity to ensure that fatigue is managed.

6.2 Template categories

In view of this evidence, specifying outer limits of 15 or 16 hours work is clearly allowing a very high accident risk if not balanced by significantly higher rest periods, frequent rest breaks within work and careful scheduling to avoid completing the work period during the circadian low.

In view of this greatly elevated accident risk especially in work periods longer than 14 hours, there is a strong argument for keeping tight control on access to even occasional or intermittent use of such long hours of work. For this reason, Work opportunities that are more than 14 hours are counted as high risk in these templates.

Work opportunities of 13 to 14 hours are counted as medium risk, work opportunities of up to 13 hours are counted as low risk and up to 12 hours as baseline or currently acceptable risk.

7 Prevent accumulation of fatigue with Reset breaks at least 30 hours and including two night periods (00:00-06:00) between work sequences

7.1 Evidence

The problem of chronic partial sleep deprivation was described above. A number of studies have shown that successive days of sleep restricted to less than 6 hours produces adverse effects on alertness and performance (Dinges et al., 1997; Van Dongen, et al., 2003; Belenky et al., 2003).

While there is a view that some people are habitually short sleepers and that most people can adapt to lower levels of sleep (Horne, 2011), the limit of safe adaptation is around 6 hours of sleep. In all of the studies of partial sleep deprivation, the accumulated sleep loss was only overcome by a significantly longer sleep opportunity.

In fact, some studies that allowed only a moderate sleep opportunity following 7 days of shorter sleep showed that even two further days of 8 hours sleep was insufficient to return alertness and performance levels back to baseline (Belenky, et al., 2003).

7.2 Template categories

The evidence shows strongly that where sleep debt has accumulated due to inadequate sleep over a period of work, longer break periods are needed to allow drivers to recover the build-up of fatigue. For these reasons, a period of at least 30 hours is needed to ensure that drivers are able to obtain sufficient sleep.

The templates were designed such that a long reset break occurring less than every seven days is viewed as high risk, a reset break after up to seven days is a medium break, after three days is low fatigue and up to 2 days is judged as baseline.

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