28 June 2019

Productivity Commission
LB2, Collins Street East
Melbourne, Victoria 8003
Submitted via online portal

Dear Sir/Madam

Freight on Rail Group (FORG) of Australia welcomes the opportunity to provide a submission on the Productivity Commission's National Transport Regulatory Reform review.

FORG represents Australia's largest rail freight operators and infrastructure owners/managers which contribute more than $11 billion to Australia's economy each year, employ almost 20,000 people, operate 1,600 freight locomotives and 34,000 rolling stock, and manage 23,000 kilometres of rail track.

Please note that FORG members may have made their own, separate (individual) submissions to the Commission (e.g. Pacific National, ARTC etc).

As you may be aware, FORG has grown increasingly concerned about negative impacts (most of them unintended) to rail freight operations caused by a raft of outdated and inconsistent state and federal policies and regulations. **Attachment A** – a FORG statement released in November 2018 – provides a clear and concise summation of these key issues.

Included in the statement is a key recommendation for the Office of the National Rail Safety Regulator (ONRSR) to be refashioned to not just maintain a focus on safety compliance, but also the timely advancement of much-needed efficiency and productivity initiatives in the rail freight sector.

The vision of the National Heavy Vehicle Regulator (NHVR) is to have *'a safe, efficient and productive'* industry. Why doesn't the rail freight sector enjoy the same level of institutional support?

In comparison to rail freight, the trucking sector – with the assistance of government – has progressed rapidly in the last decade in crucial policy and regulatory areas, notably:

- enhanced road freight productivity and efficiency, including increased axle weights and corresponding truck payloads, larger vehicle dimensions, and greater network access; and
- fatigue management, notably a shift from prescribed hours to a risk management approach.

In terms of the latter point, in August 2018, FORG and the Australiasian Railway Association (ARA) jointly commissioned a report by Deloitte Access Economics into fatigue management focused on the impact of outer limits of service in the rail freight sector (see **Attachment B**). The estimated additional costs to rail freight services (hence added costs to the overall transport supply chain) are quite startling.

Unnecessary and overly burdensome regulations in rail freight diminish and erode benefits derived from new and improved infrastructure (e.g. future Melbourne to Brisbane Inland Rail, NSW Fixing Country Rail initiative, Murray Basin Rail Project etc). They also have the affect of denting investment confidence in our sector.

With many key road freight corridors either fully upgraded or undergoing major upgrades (e.g. Hume, Pacific, Bruce, Newell, Princes, Great Western, Great Eastern and Golden highways) a regulatory environment not fully atune to the operating needs of rail freight will result in more freight shifting from trains to trucks. Ironically, this is all happening at a time when Australians want real trains, not road trains (trucks) hauling large volumes of freight.

Technology a great driver of harmonisation and efficiencies across jurisdications

FORG would also like to express its continued support for the future roll-out of ARTC's Advanced Train Management System (ATMS) on the Melbourne to Brisbane Inland Rail project. It's pleasing to see that Australian Government funding for Inland Rail includes a contribution to help to deliver this technology.

Innovative 'in-locomotive' technologies not only help enhance safety and productivity, they also allow operators to better monitor the performance of rail networks. It's an area of technical design often overshadowed by higher profile engineering/infrastructure programs, albeit the two need to go together.

New and improved technologies generate a multiplier effect in the delivery of greater network efficiencies. Australia needs to embrace such technology (including creating the right regulatory environment) to help lift the competitiveness of our regional producers, exporters and businesses.

ATMS has key features offering advantages for Inland Rail over those of alternative network train control systems:

Increased safety

Integral to ATMS is an in-cab unit overseeing a train's speed (and speed limit) and the safe distance it is permitted to travel between other trains. ATMS utilises GPS, track data and trainbourne sensors (e.g. inertial sensors) to determine the precise location of a freight train.

In the event of driver error or incapacity, ATMS can intervene and apply a train's brakes to prevent over-speed or a collision. As such, ATMS provides a level of operational safety consistent with world best practice.

Greater productivity

ATMS provides network controllers and train drivers with a capability to safely operate trains in closer proximity without the need for additional trackside infrastructure. This not only allows existing corridor capacity to be maximised but also improves network reliability and resilience.

In turn, rail freight operators achieve savings in time, fuel, maintenance and labour; helping to reduce costs for customers.

Interface with other train control systems

For example, ARTC has been in active discussions with Transport for NSW regarding the ability of ATMS to interface with the European Train Control System (ETCS – Level 2) used by Sydney Trains. This is an important piece of work considering passenger and freight trains operate on a busy shared network in Sydney.

Similarly, Queensland Rail is in the process of upgrading its passenger network to ETCS Level 2. An initial study by ARTC has determined it is technically feasible to modify ATMS to achieve interoperability with ETCS.

While there is further development work needed, ATMS and its interface with ETCS will go a long way towards harmonising digital signalling and communications across Australian rail networks.

In conclusion, if governments want safer roads, less traffic congestion during peak commute times, and lower vehicle emissions, it is imperative to work with industry to develop and implement innovative policies and regulations to help advance the rail freight sector.

Kind regards

Dean Dalla Valle
Chair
Freight on Rail Group (FORG) of Australia

Attachment A

7 November 2018

Rail freight policies languishing in the age of steam

On the eve of Australian transport ministers meeting in Sydney, the nation's largest rail freight operators and infrastructure owners said governments are getting it right on rail infrastructure, but other policies impacting the sector are languishing in the age of steam.

Freight on Rail Group (FORG) of Australia Chair Dean Dalla Valle said at a time when Australians want safer roads, less traffic congestion during their daily commute and lower carbon emissions, government policies are largely geared to rolling-out heavier and longer trucks.

"As a case in point, the National Heavy Vehicle Regulator recently approved the roll-out of a 105-tonne 36.5-metre B-Quad truck on select routes between Victoria and Queensland[1].

"Don't get me wrong: I see the obvious freight productivity benefits, but how much bigger and heavier do we want trucks on our roads to get? What's the upper limit?" said Mr Dalla Valle.

Mr Dalla Valle said the trucking industry must be congratulated for the strength and intensity of its advocacy. I admire how truckies make no apologies for being single-minded in their pursuit of extracting from governments major concessions in efficiency, productivity and road access.

"Unfortunately, rail freight has become tangled in nests of technical jargon and jumping at perceived safety risks that modern-day technology has largely eliminated," said Mr Dalla Valle.

Mr Dalla Valle gave the example of how a NSW freight train driver with more than 25-years' experience can be subjected to up to 18-months of extra training to operate on a similarly configured rail corridor in another state or territory.

"In stark contrast, a NSW truck driver can move from operating a semi-trailer for a year to handling a B-Double or Road Train[2] in just two days at minimal cost with immediate access to thousands of kilometres of road across every jurisdiction in the country," said Mr Dalla Valle.

Mr Dalla Valle said a 2017 Deloitte Access Economics report found moving nine tonnes of freight by rail instead of road between Melbourne and Brisbane saves approximately $250 in accident and emission costs[3].

"A single 1,800-metre freight train hauling containers is equivalent to removing 70 B-Double trucks from our roads. These compelling facts put rail freight firmly on the right side of every debate.

"It's disappointing the benefits of rail freight are not fully recognised or embedded in government policies. More worrying, policies aren't keeping pace with the delivery of upgraded rail infrastructure or the range of new and improved technologies available to the sector," said Mr Dalla Valle.

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[1] Australia's first B-Quad hits the road. Australasian Transport News. Tuesday 2 August 2018.
[2] Getting a heavy vehicle licence. https://www.rms.nsw.gov.au/business-industry/heavy-vehicles/licence/index.html#multicombination
[3] Value of Rail. The contribution of rail in Australia. A report commissioned by the Australasian Railway Association (ARA). Deloitte Access Economics. November 2017.

FORG is calling on the Transport and Infrastructure Council (TIC) of Australia to urgently consider the following initiatives to get rail freight policy back on track:

- **Rail freight efficiency and productivity to be given a higher priority by TIC, including a program of work in 2019 to streamline federal and state regulations to allow the proven benefits of rail freight to be fully utilised throughout Australia's transport supply chain.**

  Mr Dalla Valle said FORG members hear a lot about the need to reduce government red tape in other freight sectors, including policy proposals like trialing truck platooning on major highways and relaxing rules on the use of foreign-flagged and crewed cargo ships in Australian waters.

  "To develop polices to deliver new innovations and efficiencies, the rail freight sector is simply asking for an equal playing field. This can only be achieved by a new era of closer collaboration between government agencies, which regulate rail networks, and private companies which operate on those networks," said Mr Dalla Valle.

- **Office of the National Rail Safety Regulator (ONRSR) refashioned to not just maintain a focus on safety compliance and enforcement, but also the timely advancement of much-needed efficiency and productivity initiatives in the rail freight sector.**

  Mr Dalla Valle said ONRSR has demonstrated strong commitment and leadership to improving rail safety, and FORG would like to see the Council broaden the vision of the agency to not only continue to deliver safe railways, but also help industry enhance efficiency and productivity.

  "The vision of the National Heavy Vehicle Regulator is to have *'a safe, efficient and productive heavy vehicle industry serving the needs of Australia'*[4]. Why doesn't the rail freight sector enjoy the same level of ingrained institutional support?" said Mr Dalla Valle.

  Mr Dalla Valle also stressed the importance of other federal and state government agencies involved in the regulation of rail freight to work closer with industry.

  "The emergence of dedicated freight divisions within government transport agencies in recent years has been encouraging, but deeper engagement with private rail freight operators is needed," said Mr Dalla Valle.

- **Harmonisation of operating procedures and training requirements for freight train drivers and crews across state and territory borders by 2021.**

  Mr Dalla Valle said outside of the busy shared rail networks of Sydney, Melbourne and Brisbane, there are very few major variations or surprises to how a freight train operates on a railway line.

  "In the last decade, advances in communication and signalling technologies like sophisticated global positioning systems and state-of-the-art network control systems can now be deployed to help dramatically improve the safe running of trains," said Mr Dalla Valle.

[4] https://www.nhvr.gov.au/about-us/who-we-are/about-the-nhvr

Mr Dalla Valle gave the example of how more than 600 rail routes across Australia require a myriad of different operating codes and standards for running a freight train.

"During long-haul interstate or trans-continental trips, train drivers will travel on multiple rail networks, each having a raft of different codes, standards and communication protocols that must be adhered to. This is an area in our industry ripe for simplification, modernisation and harmonisation," said Mr Dalla Valle.

Mr Dalla Valle said the rail freight sector needs to be regulated to actual risk, not perceived risk and certainly not outdated historical risks.

"To improve rail freight productivity in this country – which directly impacts the cost of transporting goods and commodities to domestic and global markets – it's time to consign outdated and contradictory cross-border rules to the dust-bin of history," said Mr Dalla Valle.

- **Productivity Commission to investigate and quantify the impacts of mandated train driver hours on the rail freight sector; notably in Queensland and New South Wales.**

Mr Dalla Valle said the trucking and aviation sectors in Australia have shifted towards greater use of risk-based approaches to fatigue management, but rail continues to be subjected to overly-prescriptive and complex rules which often produce perverse safety outcomes.

"For example, changing over train crews when outer limits of service are reached, irrespective of the location of a train on the network, results in staff driving back and forth on roads between depots and locomotives; creating needless road safety risks and added operating costs," said Mr Dalla Valle.

Mr Dalla Valle said at times freight trains can be suddenly delayed on the network because of problems beyond the control of operators, resulting in locomotives being 'parked-up' in odd locations at odd times.

"Mandated hours for train drivers are inflexible; removing the ability for freight operators to deal with these unforeseen events with any degree of agility," said Mr Dalla Valle.

- **Recognise rail freight sector's significant contribution to reducing both accident costs and carbon emissions in Australia's transport supply chain.**

Mr Dalla Valle said a 2017 Deloitte Access Economics report found that for every tonne of freight hauled, road freight produces 14 times greater accident costs than rail freight and 16 times as much carbon pollution[3].

"I don't see any of these factors being adequately built into charging models for transport; indeed, long-overdue and much-needed reforms in the critical policy area of heavy vehicle road usage pricing have largely come to a grinding halt," said Mr Dalla Valle.

Mr Dalla Valle said meanwhile regulators continue to be preoccupied with targeting diesel emissions from freight locomotives.

"I suspect it's a lot easier for regulators to pursue the nation's small locomotive freight fleet, which operates within closed corridors, as opposed to making the effort to monitor hundreds of thousands of trucks running on Australia's massive open road network," said Mr Dalla Valle.

Mr Dalla Valle said a 2017 federal government report found freight and passenger rail transport accounted for a mere 4 per cent of total transport sector greenhouse gas emissions[5].

"In comparison, the report found heavy vehicles in 2017 accounted for more than 20 per cent of total transport emissions in Australia; growing to almost 30 per cent by 2030[5]," said Mr Dalla Valle.

Mr Dalla Valle said such 'policy prejudice' against rail will result in added regulatory burdens for freight operators, needlessly driving up operating and compliance costs in the sector.

"This will have the deleterious effect of forcing freight from rail to road, generating even higher volumes of emissions in Australia's transport supply chain," said Mr Dalla Valle.

National code of practice for diesel emissions

Mr Dalla Valle said Australia's rail freight operators had worked hard over the last two years to develop a detailed and comprehensive national code of practice for diesel emissions for existing and new locomotives.

"The code has been endorsed by the Rail Industry Safety and Standards Board and is set to be rolled out in December this year – I sincerely hope governments across the country recognise the efforts of industry, as opposed to reinventing the wheel," said Mr Dalla Valle.

[5] Australia's emissions projections 2017. Table 7: Emissons by sector (Mt CO_2-e). Australian Government. Department of the Environment and Energy. December 2017.

Deloitte.
Access Economics

Fatigue management: The impact of outer limits of service in the rail sector

August 2018

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Executive summary

Deloitte Access Economics has been commissioned to investigate and quantify the impacts of outer limits of service for train drivers in Australia. Outer limits of service refers to legal or regulatory limits around work and rest. Outer limits of service currently apply for train drivers in New South Wales and Queensland as an additional legislative requirement for rail operators to manage fatigue.

Current and potential impacts in Australia

In order to quantify the impacts of outer limits of service, Deloitte Access Economics has developed four case studies, utilising data and other information provided by industry:

- two case studies quantifying the current costs worn by Aurizon and Pacific National to comply with outer limits of service for train drivers; and
- two case studies estimating costs that could occur for a Pilbara operator and TasRail if outer limits of service for train drivers were introduced in their respective jurisdictions.

The results of the case studies are summarised in Table i, below.

Table i Case study results – estimated costs of outer limits of service

Operator	Current or potential	Cost category	Value	
Aurizon – Blackwater Rail Corridor*	Current	Staff costs	$283,000	
		Road vehicle operating costs	$221,000	
		Road use externalities	$63,000	
			$567,000	Annually
Pacific National – Goonyella Rail Corridor#	Current	Staff costs	$722,000	
		Road vehicle operating costs	$81,000	
		Road use externalities	$23,000	
			$826,000	Annually
Pilbara iron ore miner	Potential	Capital costs[1]	$10,000,000	One-off cost
		Staff costs[2]	$50,400,000	
		Capital O&M	$300,000	
			$50,700,000	Annually
TasRail	Potential	Capital costs	$7,000,000	One-off cost
		Staff costs	$698,000	Annually

* This case study only applies to part of the network.

This case study only applies to one service on the network, Pacific National services at least 12 mines in the Goonyella System.

Source: Deloitte Access Economics calculations using rail operators' inputs.

[1] There is significant uncertainty around this figure. The rail operator has advised that the cost would be "in the tens of millions of dollars."

[2] Staff costs in this case study include: base salary, FIFO allowance, superannuation, flight assistance, bonuses, and other special awards.

The **Aurizon** and **Pacific National** case studies are similar in nature. The costs in both relate to the need to change crews and use road vehicles when outer limits of service are reached. This creates staff costs, road vehicle operating costs (both of which are born by the rail operator) and adverse safety implications through road use externalities (which includes costs associated with fatalities, injuries and property damage due to road accidents). In the Aurizon case study, it is estimated that outer limits of service for train drivers create the need to travel around 350,000 kilometres per year by road changing train driver crews; and in the Pacific National case study, the figure is around 128,000 kilometres. It must be highlighted, that these case studies consider only a part of the respective networks and, as a result, it is likely that the overall cost implications for Aurizon and Pacific National to comply with the train driver outer limits in NSW and Queensland are more substantial.

The case studies relating to a **Pilbara** iron ore miner and **TasRail** also have similarities in nature. The Pilbara iron ore operator currently operates using 12-hour driver only shifts. The Pilbara iron ore operator advised that complying with outer limits of service akin to what is in place in Queensland or NSW would require the construction of a new depot, costing "in the tens of millions of dollars." It is believed that, to continue operating at current levels, while complying with outer limits of service, the increase in train driver numbers could be in the order of 225, a 50% increase (from current levels of around 450 drivers).

In the case of TasRail, the $7 million capital costs noted in Table i relates to the purchase of additional rolling stock and facility upgrades to allow current production levels to be maintained with the use of fewer services (due to the loss of time associated with additional crew changes). The $698,000 yearly additional staff costs are driven by the fact that TasRail currently operates solely using driver-only services, and compliance with outer limits of service will involve the need to hire additional staff.

As for all case studies, there is uncertainty around the results. Their calculation has required rail operators to consider how their operations would be different under counterfactual situations where data is challenging to generate. Deloitte Access Economics has not independently verified the data.

A common theme across consultations with rail operators was that staff time spent driving on roads is among the greatest safety risks that rail operators face. By creating the need to change crews whenever outer limits of service are reached, irrespective of the location of a train, outer limits of service can significantly heighten a rail operators' risk profile.

If cost increases due to outer limits of service lead to higher prices for rail freight, this could lead to substitution towards road freight which could have greater costs for society. Road freight has accident costs (including fatalities and injuries to people and damage to property) around 14 times greater than rail freight (on a tonne kilometre basis) (Deloitte Access Economics, 2017).

There are also other costs and potential costs that have not been quantified. For example, recruitment and training costs have not been included in the analysis. According to the industry, introduction of outer limits of service for train drivers without a transition period in the order of 24 months could potentially jeopardise currently contracted arrangements given the lack of appropriately trained staff.

It could be argued that the ability to gain exemptions to outer limits of service, where a safety case can be made, means that rail operators would not be impacted by outer limits of service. However, there are costs to achieving exemptions. Pacific National has estimated that staffing costs and consulting fees were in the order of $59,000 for an exemption it has secured in Queensland.

Fatigue management in practice

The transport industry is generally moving toward risk-based approaches to fatigue management. Both the heavy vehicle and aviation sectors in Australia have shifted towards greater use of risk-based approaches. The maritime sector still uses outer limits of service, with approvals for risk-based approaches on a case-by-case basis.

Both the heavy vehicle and aviation sectors in Australia have a tiered approach to fatigue risk management. Reliance on outer limits of service to manage fatigue risk is generally a concession for smaller and less sophisticated operators. At the lowest tier, drivers or pilots must comply with prescribed limits on hours of work. At the other end of the hierarchy, only operators accredited for Advanced Fatigue Management in the heavy vehicle sector and those approved to operate under a fatigue-risk management system in the aviation sector can exercise greater flexibility by adopting a risk-based approach to manage fatigue.

By contrast, all rail operators in Australia are already required to employ a risk-based approach under the Rail Safety National Law and Regulations. They all need to demonstrate their competency and capacity to safely operate a railway, including how they roster staff and manage fatigue. This reflects the fact that the rail industry is predominantly made up of larger, more sophisticated organisations and also that investments have been made into engineering and technical approaches to managing fatigue related risks within the rail industry.

Evaluating outer limits of service from a safety perspective

A literature review has not revealed evidence that outer limits of service for train drivers improves fatigue management relative to risk-based approaches. Empirical evaluations have historically found that duty periods are positively correlated with fatigue and accidents, but these studies do not consider or control for other influences. Risk-based approaches *explicitly* seek to consider and control for the range of factors that impact fatigue as well as mitigate the consequences of fatigue-related impairment.

Of particular relevance to Australia, there appears to be no evidence that safety outcomes are improved by imposing outer limits of service within a risk-based approach (as is done in Queensland and NSW at present).

A note on national inconsistency

Aside from the costs that outer limits of service create, the inconsistencies relating to outer limits of service between Queensland, NSW and the rest of Australia creates costs for rail operators due to the need to manage compliance with different regulations in different jurisdictions.

The Productivity Commission (2012) has argued that "reforms which reduce the costs to operate across jurisdictional borders… have the potential to increase competition in affected markets. Over time, lower 'border' costs may mean more businesses find it profitable to operate interstate, which could result in increased competition and greater incentives for innovation, and therefore enhanced productivity."

The costs of inconsistency in itself have not been analysed in this report. However, all 44 rail operators (a quarter of all rail operators in Australia) who operate across some combination of Queensland, NSW and the rest of Australia would experience some costs due to allowances made for Queensland and NSW in Schedule 2 of the Rail Safety National Law Regulations.

Conclusion

Overall, this report finds that:

- Current outer limits of service for train drivers impose significant costs which would likely extend to other jurisdictions if outer limits of service applied there too.
- The transport industry is generally moving toward risk-based approaches to fatigue management.
- There does not appear to be evidence that outer limits of service for train drivers improves fatigue management relative to risk-based approaches.

Deloitte Access Economics

1 Introduction

The Office of the National Rail Safety Regulator (ONRSR) is conducting a review on behalf of the Transport and Infrastructure Council (TIC) of the fatigue provisions within the Rail Safety National Law (RSNL).

Deloitte Access Economics has been commissioned to investigate and quantify the impacts of outer limits of service for train drivers in Australia. This report presents the results of that research and is organised as follows:

- Chapter 2 briefly describes what fatigue is.
- Chapter 3 discusses the concepts of outer limits of service and risk-based approaches to fatigue risk management, including available information evaluating each approach.
- Chapter 4 provides information on the risk management approaches taken in Australia's transport sectors, and transport sectors in other countries.
- Chapter 5 provides quantitative estimates of the actual and potential impacts of outer limits of service in Australia's rail sector.

The terms 'mandated hours', 'outer limits of service', 'outer limits of work and rest' and 'prescribed outer limits' are commonly used interchangeably within the industry to refer to approaches to fatigue management that rely on regulated maximum hours of work.

In this report, we use the phrase 'outer limits of service'.

2 Fatigue and safety

In the context of work and safety, fatigue is an impaired state, or subjective state of exhaustion that prevents an individual from working safely and efficiently. Fatigue is a complex phenomenon with a range of work-related and non-work-related factors that contribute to the development of a fatigued state.

With operations running 24/7 in the transport sectors and the need for constant vigilance and interaction with technical systems and machinery, workers in the transport sector are likely to experience exposure to situations that can contribute to fatigue and have significant implications for the safety of railway operations. As such, the need to manage fatigue and its negative effects is essential for the rail industry.

Many factors of fatigue relate to an individual's body clock and sleep loss. Primary contributors to fatigue include reduced duration of sleep, extended hours of time awake and disturbances to times that an individual is awake and asleep (Fourie et al., 2010). According to Fourie et al. (2010), and Bowler and Gibson (2015), both work-related and non-work-related factors contribute to fatigue, and generally fall under the following three categories:

- **Individual factors** include (but are not limited to) lifestyle factors, drug and alcohol use, and medical conditions such as sleep disorders.
- **Environmental factors** include (but are not limited to) the quality of an individual's sleeping environment (affected by factors such as ambient temperature and noise levels), family circumstances and domestic responsibilities.
- **Work-related factors** include (but are not limited to) the timing of work and rest periods, the length and number of consecutive work duties, and the nature of the work.

A rail safety worker could become impaired by fatigue due to one or more of these factors, which could compromise rail safety and contribute to a rail accident. For example, a rail safety worker may have difficulty sleeping well while taking care of a young family or potentially due to health issues such as sleeping disorders (Brake, 2016; Bowler et al., 2015). The rail safety worker may also then experience a particularly challenging set of work related factors, such as transitioning to a later shift start time and a particularly challenging route, such as one that involves multiple level crossings. In this situation, the rail safety worker would be experiencing a range of factors (individual, environmental and work-related) that come together to contribute to a state of fatigue.

3 Managing fatigue

At both an individual and organisational level, the negative impacts and consequences of fatigue reflect the obligation for it to be effectively managed and ensure the safety of rail operations, so far is reasonably practicable (SFAIRP).[3] Currently, approaches in Australia's rail sector to manage fatigue can broadly be categorised as:

- outer limits of service; and
- risk-based approaches.

There is potential for outer limits to be included within a risk-based approach, as is the case in Australia's rail sector in Queensland and NSW at present. The outer limits of service for train drivers imposed in Queensland and NSW are different though.

Generally speaking, outer limits of service approaches seek to manage fatigue-related risk by controlling one of the factors (hours of work) that can contribute to fatigue-related impairment. On the other hand, risk-based approaches take a holistic view to achieving the outcome of reducing fatigue-related risks by considering a range of factors that may contribute to fatigue, as well as understanding and mitigating the consequences.

A potential strength of outer limits of service is that they introduce a clear limitation around one of the factors affecting fatigue.[4] A consequence of that clarity is that it creates rigidity in the system, which may actually impede rail operators' ability to manage fatigue holistically and flexibly. The flexibility that operators can build into their operations under a risk-based approach also allows them to maximise productivity. This flexibility does, however, mean that operators and those regulating them need to be sufficiently mature and sophisticated in identifying and managing risks. Table 3.1 summarises of the strengths and weaknesses of the two approaches.

Ultimately, achieving good risk management practices requires competency and capability within the organisation. To be an accredited rail operator, a rail operator must demonstrate its competency and capacity to safely operator a railway. A railway does this through its Safety Management System and Fatigue Risk Management Program, both of which are reviewed in the accreditation process by ONRSR.

In addition, these approaches to managing fatigue related risks are also complemented by engineering controls. Engineering controls for risk management are used extensively within the Australian rail industry and include approaches such as Automatic Train Protection (ATP). The Australian rail industry has made significant investments in engineering controls to manage risks within a risk-based approach to fatigue management.

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[3] This approach has been enshrined within rail safety law in Australia since the Model Rail Safety Bill was introduced in 2006. With the advent of the Rail Safety National Law, the concept remains as one of the central tenets for achieving a safe railway.

[4] 'Potential' because the clarity of the limitation depends on the clarity of the legislation or regulation. Compliance can be complicated by vagueness or indeterminacy in language.

Table 3.1 Strength and weaknesses of fatigue management approaches

Fatigue Management Approach	Strengths	Weaknesses
Outer limits of service	• Simplicity of interpreting and enforcing limited hours. • Limiting the amount of time that is spent work. • Potentially limiting the duration of continuous time on a task. • Ensuring a minimum number of opportunities for sleep and other non-work activities. • Defining minimum breaks for sleep and recovery.	• May not take into account the daily cycle of the circadian biological clock. • Overlooking the greater fatigue risk of work during night time and the smaller recovery value of sleep opportunities during day time. • Not addressing the duty cycle, which overlooks accumulated sleep debt and dose-dependent effects on performing at work, and the frequency of opportunities for full recovery from sleep debt. • Non-work-related time is not included in the calculation of rest opportunities, such as commuting, and the behaviours and schedules outside of work cannot be mandated. • May put workers at unnecessary risk; for example, employees being required to travel by road to relieve train crew who have reached their outer limit, whereas the safest action may be to allow the train crew to continue working their train to the next depot. • Not considering the effect of external commitments that affect the ability to have quality rest.
Risk-based approaches	• Consideration given to the hierarchy of controls i.e. developing solutions to mitigate unintended consequences. • More flexible and proactive manner of adapting to the nature of an organisation's operations. • Encourages consideration of the range of factors that affect fatigue, such as: – the length of time awake that is required for work; – the duration of continuous time on a task; – the daily cycle of the circadian biological clock fatigue across the duty cycle; – the nature of the task, and how work is designed and planned; and – involves workers in fatigue-management decisions during day-of-operations.	• Regulators, employers and employees need to better understand the complex relationships between risk and safety for risk-based approaches to be effective. • Regulators, employers and employees are required to sufficiently understand the causes and outcomes of fatigue in order to meet their responsibilities within risk-based approaches. • The effectiveness and operation of risk-based approaches is dependent on an organisation's size, complexity, competency and integrity. • The flexibility of the approach means it may be more difficult to regulate or enforce.

3.2 Outer limits of service

Outer limits of service rely on prescribed hours of work and rest, by explicitly limiting the maximum number of working hours and providing for mandatory minimum rest breaks (Gander et al., 2011). Regulators provide limits on the hours of service in the aim of balancing working conditions and remuneration (Gander et al., 2011) for industry workers.

In NSW and Queensland, train driver hours are prescribed, with different prescriptions in each jurisdiction. ONRSR highlights that in broad terms, the outer limits of service for train drivers relate to:

- maximum shifts and shift lengths depending on whether it is freight or passenger vehicles, and whether it operated by one or two people;
- minimum break length between shifts depending on whether the driver is taken to or away from the home depot;
- maximum numbers of shifts and hours in any 14-day period; and
- requirements in relation to the maximum length of time allowed between signing on for a shift and reaching the home depot or barracks when travel is involved in getting to the home depot or barracks.

Gander et al. (2011) states that as well as the simplicity of interpreting and enforcing limited hours, the key strength of regulating hours of service is limiting exposure to some of the causes of fatigue, such as by:

- limiting the length of the time awake for work;
- limiting the (continuous) time taken for tasks; and
- creating opportunities for sleep and other non-work activities.

Outer limits of service generally focus only on the time spent on task. This approach risks simplifying fatigue management, as it leads to natural limits in the ability to identify when fatigue is in play, how it could be affecting a rail safety worker and its implications for the frequency or severity of a rail safety incident. For example, a rail safety worker may face a difficult and long road commute to work through peak hour traffic, which could significantly add to the worker's fatigue even before they start working.

This means that **outer limits of service are not always effective in managing fatigue, and can result in adverse consequences** (Gander et al., 2011). Typically, outer limits of service regulations require additional strategies to manage fatigue-related hazards (Dawson & McCulloch, 2005) and many of the key causes of fatigue are not being managed under outer limits of service. Factors that impact fatigue but are not addressed by outer limits of service include:

- the effect of daily cycle of the circadian biological clock (overlooking the greater fatigue risk of work during night time and the smaller recovery value of sleep opportunities during day time);
- the duty cycle (overlooking cumulated sleep debt and dose-dependent effects on performing at work, and the frequency of opportunities for full recovery from sleep debt); and
- non-work-related time in the calculation of rest opportunities, such as commuting, and the behaviours and schedules outside of work.

Furthermore, under outer limits of service there can be variations or uncertainty on when the limited hours start and end. For example, a rail driver's nine-hour shift could start either when they commence their shift or could potentially start when they actually start actively operating the locomotive. The precise approach must be set out in legislation, not finely adapted to the particular task at hand.

3.3 The risk-based approach

An alternative to this is the risk-based approach. A risk-based approach does not rely on mandated requirements but, rather, relies on comprehensive assessments of the relevant factors that contribute to fatigue, the consequences of fatigue related impairment in a given situation, and an appropriate risk management strategy that is targeted to address those factors and consequences.

Under risk-based approaches, organisations tailor their Fatigue Risk Management Program to manage the level of exposure of fatigue risk. The approach to managing the risk is based on the nature of the operation and tailored to the work environment (Gander et al., 2011). In comparison to limited hours, risk-based approaches involve a holistic view of risks that are associated with a specific task. Controls are then identified to be implemented to address fatigue risks.

By considering the factors and their contribution to fatigue related risks for each task, risk-based approaches can potentially target certain tasks, and their overall risk of fatigue. Risk-based approaches could minimise safety risk by tailoring work-related rest-breaks during shifts, recover breaks between shifts, and resetting breaks towards a worker's likelihood of fatigue.

Overall, risk-based approaches aim to take a more scientific and data-driven approach to understanding and minimising the causes and adverse impacts of fatigue, as far as is reasonably practical (Gander et al., 2011; Civil Aviation Safety Authority, 2016).

Safe Work Australia (SWA) (2013) "provides practical guidance for persons conducting a business or undertaking and other duty holders on how to ensure it does not contribute to health and safety risks in the workplace". This includes guidance on how various factors that contribute to fatigue translate into risks and potential control measures. Figure 3.1 below is an excerpt from SWA (2013) relating to fatigue risk management.

Figure 3.1 Excerpt from the SWA risk management chart

Step 1: Hazard Identification Identify potential hazards and risks at the workplace. Examples of some factors that contribute to fatigue are listed below. Consider these factors in the context of your specific workplace or industry.

Step 2: Risk Assessment To assist risk assessment, a general level of risk for each hazard is indicated along arrow guides. In assessing risk consider interaction between hazard factors that could influence the level of risk. Also take into account specific workplace/ industry circumstances that may influence it.

Step 3 Risk Control Where a hazard factor is assessed as medium/ higher risk, consider implementing control measures, such as those outlined in section 2 of this code.

Factors that contribute to Fatigue	General risk indicator for factors that contribute to fatigue				Control measures
Work Scheduling and Planning **Hours**	Lower risk			Higher risk	**The most appropriate control measures should be implemented for the identified risk factor.** **Control measures may include:**
■ Average weekly hours (other than FIFO)	35-40 hours (working week)		48 hours (working week)	56 hours (working week)	■ Scheduling safety critical work outside low body clock periods (i.e. between 2am and 6am)
■ Total hours over a three month period (other than FIFO)			624 working hours		■ Structure shifts and work plans so that demands are highest towards the middle of the shift and decrease towards the end
■ Daily work hours		9 working hours	12 working hours		■ Use forward rotation roster systems (day-evening-night)
■ Daily work hours and work-related travel, including commute			10 working hours	13 working hours	■ Designing working hours and rosters to provide for adequate sleep opportunity (considering time for eating, washing, personal commitments etc)
■ Scheduling of work	Regular, predictable hours		Irregular and unpredictable hours, short notice of schedule, extended overtime, on call across shift cycle		■ Monitor actual time worked against the allocated roster and indentify if excessive hours are being worked
Shiftwork	Lower risk			Higher risk	**Additional control measures should be implemented for special work arrangements and can include:**
■ Length of shift (other than FIFO)			10 hours	13 hours	■ Considering sleep opportunity and recovery in instances where workers are required to work on call after a normal shift or on days off
■ Time of shift	Day shift		Afternoon shift	Night shift	■ Avoiding quick shift changeovers, such as finishing at 11pm and starting again at 7am
■ Speed and direction of shift	Forward rotation (morning/afternoon/night		Backward rotation (night/evening/ morning)	slower rotation (i.e. weekly / 3-4 weekly rotation)	■ Use forward rotation roster systems (day-evening-night)
■ Split shifts and variable shifts				13 hour period	■ Allocate shift and night workers consecutive days off to allow for at least two full nights rest including some weekends

Source: Safe Work Australia, 2013

The key strengths of risk-based approaches lie in the flexible and proactive manner of adapting to the nature of an organisation's operations that they provide for (Gander et al., 2011). Gander et al. (2011) also states that risk-based approaches have the potential to consider and manage exposure to a wide range of causes of fatigue, including:

- the length of time awake that is required for work;
- the duration of continuous time on a task;
- the intensity of work demands (workload);
- the daily cycle of the circadian biological clock; and
- fatigue across the duty cycle.

As the risk-based approach is more complex and nuanced, there is a need for are a number of associated challenges. In particular, "a better understanding is needed on the complex relationship between fatigue and safety" for risk-based approaches to be effective (Gander et al., 2011, p.586).

The effectiveness of such regulation at managing fatigue in practice may depend upon enforcement of non-compliance. There is potential for non-prescriptive approaches to be abused if regulatory enforcement is unlikely (Gander et al., 2011).

Another factor that can enhance the effectiveness of a risk-based approach is complementary engineering controls. Engineering controls involve physical systems built into the rail network and rolling stock that manage risks related to fatigue. An example of one of these types of controls is Automatic Train Protection. The Australian rail industry has made significant investments in engineering controls to manage risks within a risk-based approach to fatigue management.

Finally, the effectiveness and operation of risk-based approaches is dependent on an organisation's size and complexity. Smaller, less mature operators might struggle to cover the individualised costs of developing a safety case for the use of risk-based approaches.

3.4 Evaluation of different approaches

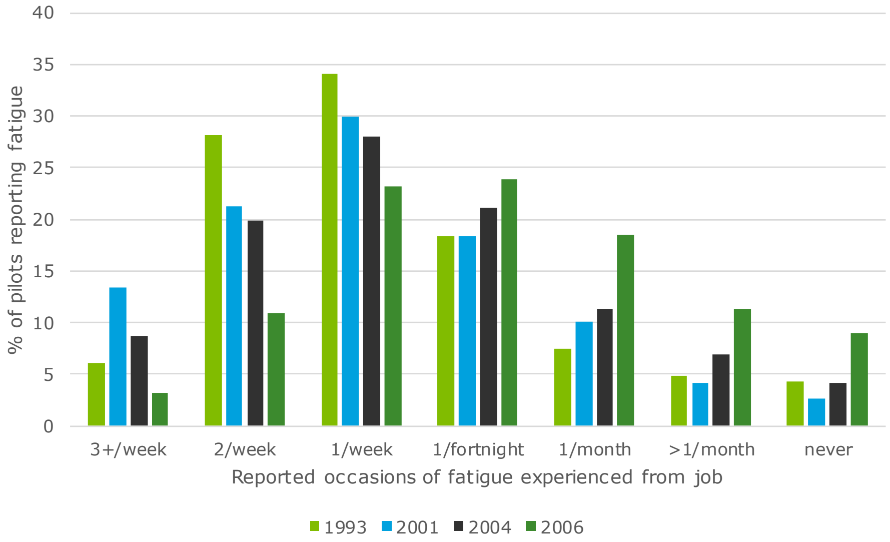
Empirical evaluations have historically indicated that duty periods are positively correlated with fatigue and accidents (Goode, 2003; Dembe et al., 2005; Pylkkönen et al., 2013). In isolation, this may appear to provide evidence for limiting duty periods. However, these studies do not consider or control for the other drivers of fatigue. As outlined in Chapter 2 above, fatigue is caused by a number of factors. In practice, a single night of limited sleep does not result in significant declines in performance; but when sleep is restricted over a period of 14 nights there is evidence of clinically significant reductions in performance across multiple measures of neurobehavioral performance (Dawson & McCulloch, 2005).

As a result, shift lengths should be considered in balance with other drivers of fatigue in making predictions about fatigue and safety impacts, as is facilitated through a risk-based approach to fatigue management.

A review of the literature did not uncover any empirical evaluations of comprehensive fatigue risk management systems. There is evidence to suggest that a holistic approach to fatigue risk management that addresses hours of work, and other factors offers better outcomes for both the safety of the organisation and the wellbeing of workers.

Air New Zealand introduced a comprehensive fatigue risk management scheme in 1993. The frequency with which pilots reported being impaired by fatigue dropped significantly (shown in Chart 3.1 below). In 1993, the majority of pilots reported experiencing fatigue at least once a week. By 2006, the majority of pilots reported experiencing fatigue less than once a fortnight (Gander et al., 2009).

Chart 3.1 Air New Zealand flight crew fatigue reporting following the introduction of a risk-based approach to manage fatigue in 1993



Source: Gander et al., 2009

Similar findings were made by McCulloch, Fletcher and Dawson (2003) in their evaluation of the shift from a prescriptive framework to a risk based approach to fatigue regulation. Sixteen operators of passenger and business aviation services were evaluated. The study collected qualitative responses from staff and examined the policies and training materials of operators. The study identified a generally positive response by managers and flight crew to the change in relation to operations and to personal experience.

The implication from this research is that while shift lengths are correlated with operator fatigue, they cannot be considered in isolation. Fatigue risk management programs can achieve the mutually desirable goals of operational flexibility as well as enhancing workplace moral and improving safety performance.

4 Fatigue risk management in practice

There is a mix of both forms of fatigue risk management across transport sectors in Australia and rail industries in other countries. In rail in Australia, the Rail Safety National Law and regulations create a consistent framework for fatigue risk management, but Queensland and NSW deviate from this approach with the imposition of their own specific outer limits of service for train drivers. The heavy vehicle and aviation sectors in Australia follow a mixed approach of both forms of fatigue management, while in Australia's maritime sector a risk-based approach is available with approval.

Currently, in other transport sectors overseas, New Zealand has been the most focussed on implementing risk-based approaches, Canada has shown similarities to Australia's mixed approach, while the US is still using outer limits of service. Figure 4.1 shows the current status of each transport sector in Australia and key overseas countries.

Section 4.2 describes fatigue risk management in Australia's transport sectors in more detail, while Section 4.3 does the same for other countries.

Figure 4.1 Fatigue managements in Australia and overseas

Country	Rail	Road	Aviation	Maritime
Australia	Elements of both	Elements of both	Elements of both	Limited hours
United Kingdom	Risk-based approaches	Limited hours	Elements of both	Limited hours
United States	Limited hours	Limited hours	Limited hours	Limited hours
Canada	Limited hours	Elements of both	Elements of both	Limited hours
New Zealand	Risk-based approaches	Limited hours	Risk-based approaches	Risk-based approaches

Risk-based approaches | Limited hours | Elements of both

4.2 Transport sectors in Australia

Rail – Australia's rail industry is required to implement a risk-based approach to fatigue management. However, operators in NSW and Queensland have additional fatigue management compliance requirements, as train drivers in NSW and Queensland must work within prescribed outer limits of service. The other transport sectors in Australia – heavy vehicle, aviation and maritime industries –are tending to transition towards risk-based fatigue management.

There are variations on how the outer limits of service differ for train drivers in NSW and Queensland, which are summarised in Appendix A. Broadly, the two approaches apply limits of 8, 9, 10, 11 or 12 hours depending on whether it is freight or passenger and other factors such as the location of the depot. There are minor but material differences in other parts of the regulations as well with, for example, NSW's approach including additional breaks for drivers during the shift but less break between shifts than Queensland's approach. In Queensland, there is also an overall limit of 132 hours of work within a 14-day period while in NSW the limit is based on the number of 12-hour shifts within a 14-day period.

Achieving a nationally consistent approach to safety and fatigue risk management in rail has been a longstanding goal of Australia's rail industry and policymakers. At present, all jurisdictions in Australia must manage fatigue risk using a risk-based approach, but NSW and Queensland also impose outer limits of service for train drivers (and the limits are different in each state). This inconsistency introduces red tape and increases compliance costs for businesses and workers operating across multiple jurisdictions. The ONRSR has indicated that 44 of 185 accredited Australian rail operators are impacted by the difference in regulations between Queensland, NSW and the rest of Australia.

A nationally consistent approach to rail safety management aims to not only improve the safety outcomes for rail workers, passengers, and the community at large, but also to generate efficiencies for rail, improve service quality, enhance job appeal and reduce costs (Webb, 2000). The Productivity Commission (2012) has argued that "reforms which reduce the costs to operate across jurisdictional borders (both between and within States) have the potential to increase competition in affected markets. Over time, lower 'border' costs may mean more businesses find it profitable to operate interstate, which could result in increased competition and greater incentives for innovation, and therefore enhanced productivity."

Leaving aside the benefits of national consistency in itself, imposing outer limits of service has the potential to increase costs for rail operators and reduce other aspects of safety for train drivers and the community (for example, where adherence to the limits increases the use of road travel).

Commercial vehicles – In 2008, Heavy Vehicle Driver Fatigue regulations replaced the traditional limited hours. Under these regulations, a mix of both traditional limited hours and a risk-based approach comprise three tiers: Standard Hours, Basic Fatigue Management (BFM) and Advanced Fatigue Management (AFM). Operators were given the duty to manage their workers' fatigue, and shared legal responsibility to prevent driver fatigue was given to a number of parties in the supply chain in road transport who were identified as influencers of driver fatigue (Fourie et al., 2010).

'Standard hours' apply to drivers that are not accredited for fatigue management, and includes prescriptions around shift and rest length for different types of operations (solo driver, bus driver, etc.). When operators are accredited for Basic Fatigue Management (BFM) or Advanced Fatigue Management (AFM) they can exercise greater discretion in how they operate their businesses and apply a risk-based approach to fatigue management. The expertise required for BFM and AFM in the trucking industry aligns more closely with that of Australia's rail operators than that of trucking operators operating under Standard Hours.

Aviation – In 2013, the Civil Aviation Safety Authority (CASA) introduced a three-tier approach for the aviation industry in Australia by allowing operators to follow either form of fatigue management, or a mix between the two (CASA, 2013). Introduction of this approach was driven by *The Independent Review of Aviation Fatigue for Operators and Pilots*, prepared for CASA. The approach emphasised the need to be more risk-based and data driven to understand the science behind fatigue management. A risk-based approach is deemed appropriate where scaled to the diversity of operations, while also taking into account unique operational environments more adequately (Dédale Asia Pacific, 2013).

Maritime – The Australian maritime industry is regulated with outer limits of service, while granting approvals for risk-based approaches. Under the *Marine Order 54 (Coastal pilotage) 2014*, licensed pilots must comply with the default Fatigue Risk Management Plan (FRMP) published by the Australian Maritime Safety Authority (AMSA), or an alternative FRMP approved by AMSA. The default FRMP sets out minimum mandatory leave requirements and rest periods between pilotage tasks, such as a pilot is required to have at least five consecutive nights of rest at home for any roster cycle exceeding 21 days, with a maximum of 28 days for any roster cycle. Exemptions require pilots to monitor and manage their own fatigue risk under their hours of work and rest. These exemptions are approved as an alternative FRMP by ensuring the following criteria:

- The controls and treatment of fatigue-related risks associated with the alternative FRMP;
- Ensuring rosters are scheduled adequate leave and rest periods between pilotage tasks;
- Medical assessment on pilots' fitness for duty, and facilitating adequate fatigue management training;
- Clear responsibilities carried out across all positions under pilotage operations; and
- Adequate measures of monitoring and recording pilot hours of work and rest abroad vessels.

4.3 Transport sectors in other countries

This section provides information on the regulation of fatigue in the New Zealand (section 4.3.1), United Kingdom (section 4.3.2), the United States (section 4.3.3), and Canada (section 4.3.4).

4.3.1 New Zealand

Rail – Under the Railways Act 2005, there is no specific fatigue related regulation in New Zealand. Rather, New Zealand legislates general safety duties of rail and safety workers, whereby each operator must have policies that ensure their workers are not impaired as a result of fatigue (ONRSR, 2018).

Commercial vehicle industry - Commercial drivers in New Zealand have followed outer limits of service to manage fatigue. Since 2007, the differentiation between driving hours and duty hours has been abolished, and both are limited to a maximum of 13 hours per 24 hours (Gander et al, 2011; NZ Transport Agency, 2018b).

However, New Zealand is currently awaiting approval for an alternative fatigue management scheme (AFMS), which allows approved operators to proactively manage fatigue under their own risk-based approach. This involves approved operators managing their own work and rest time limits for their drivers. It is possible under an AFMS for an operator to permit variations in rest break limits or extend their cumulative work day (NZ Transport Agency, 2018a).

Aviation – New Zealand's aviation industry has the longest experience with risk-based approaches to fatigue management (Cabon et al., 2012). Since 1995, New Zealand operators in the aviation industry were able to either comply with regulated hours of service, or apply to the New Zealand Civil Aviation Authority to implement an alternative risk-based approach (Signal et al., 2009). Gander et al. (2011) states that the risk-based approaches require considerations on the factors that may cause fatigue, including:

- rest periods prior to and in flight;
- effects of time zone changes and night operations;
- crew composition;
- type and amount of workload; and
- the cumulative effects of work.

Maritime – New Zealand's maritime vessels were covered by amendments to the OSH legislation in 2003. Since 2003, Maritime New Zealand has been in charge of regulating fatigue management. As well as requiring certification, the maritime industry began regulating and developing risk-based programs under the existing safety management system, the Safe Ship Management Programme. In turn, the maritime industry in New Zealand fell out of international conventions and have not used prescribed limited hours of work and rest, with the exception of watch keepers on international vessels.

4.3.2 United Kingdom

Rail – For the rail industry in the United Kingdom, limited hours for both hours of work and rest were replaced by risk-based approaches in 2006, under 'Regulation 25 – Fatigue' of The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (Bowler and Gibson, 2015).

The Office of Rail Regulation (ORR) also published guidance on developing a comprehensive risk-based approach where employers are given specific duties to ensure safety-critical tasks are operated by employees that are not affected by fatigue (Bowler and Gibson, 2015; ONRSR, 2018). This also applies to duty holders, as well as employees.

Commercial vehicles – Under the Management of Health and Safety at Work Regulations (1999), drivers and journey risks must be assessed, and all reasonably practical measures must be placed to ensure drivers do not exceed working limits and driver hours in managing fatigue (Brake, 2016; RSSB, 2013).

Since the 2006 regulation under the European Commission (Department of Transport, 2014), both goods and passenger-carrying vehicle drivers in the UK must comply with regulations of limits of service and rest either under the European Union (EU) Drivers' Hours Rules or (Great Britain) GB Drivers' Hours Rules, or a mix of both – depending on the country of the driver's journey.

The main EU Drivers' Hours Rules limit drivers to nine hours a day (can be extended to 10 hours twice a week at most), and a maximum of 56 hours in a week, and 90 hours in any two consecutive weeks.

The GB Drivers' Hours Rules on the limits to driving, duty, rest and breaks vary between goods and passenger-carrying vehicles. In general, exempted goods vehicle drivers following GB Rules are limited to a maximum of driving 10-hours and 11 hours of duty in any day (Gov.uk, n.d.).

Aviation – From 2016 onward, the aviation industry in the UK has transitioned to the European Aviation Safety Agency (EASA) Subpart Flight Time Limitations (FTL) (UK Civil Aviation Authority, 2015a). This transition is a step closer towards implementing risk-based approaches. All operators are not only responsible for allocating work and rest limitations, but to prescribe them under the consideration of fatigue risks within their operational context, such as the circadian rhythm and time-zone crossing (UK Civil Aviation Authority, 2015a; UK Civil Aviation Authority, 2015b; The Transport Committee, 2012). As a result, operators must demonstrate an adequate level of safety in compliance with time limits of service. Risk-based approaches are encouraged to be developed and implemented over time, unless an operator's risk-based approach is approved to continue under the EASA Subpart FTL (UK Civil Aviation Authority, 2016; UK Civil Aviation Authority, 2015b).

Maritime – The UK maritime industry manages fatigue by monitoring and managing the hours of work and rest, following compliance with various international conventions. From April 2018, the UK's Merchant Shipping (Hours of Work) Regulations have been updated with minimum leave and rest periods.

4.3.3 United States

Rail – The United States continues to use limited hours for work and rest but it must be noted that the US Regulator implements prescriptive regulation (ONRSR, 2018; Office of Research and Development, 2006). In 2011, there have been amendments on adding substantive hours of service in terms of: maximum on-duty periods for each group of workers, minimum off-duty periods for train and signal employees, and additional limitations on consecutive days and certain monthly limitations on the activity of rail workers (NTC, 2012; ONRSR, 2018).

Commercial vehicles – In 2011, the US Federal Motor Carrier Safety Administration (FMCSA) published the Hours of Service of Drivers Final Rule, which involves regulating commercial road transport with outer limits of service. The regulations apply to both property-carrying and passenger-carrying drivers and are summarised in Appendix A (FMCSA, 2011).

Aviation – In 2011, the US Federal Aviation Administration (FAA) amended the regulations limiting hours of service and rest time to manage fatigue. Outer limits of service regulations include: the nine-hour maximum flight time, and eight hours at night; and a rest period of 10 hours, with the opportunity for at least eight hours of uninterrupted sleep (Houston, 2017; Joyner, 2018).

The FAA also recognises that the updates on the outer limits of service would not manage fatigue risk alone. The FAA has proposed each airline to implement a risk-based approach for operators to mitigate the risks of fatigue (FAA, 2011; Houston, 2017), and sponsored by multi-disciplinary subject matter expert work group (FAA, 2014).

Maritime – Since 2012, the US maritime industry has updated their hour limits of work and rest to manage fatigue in compliance to the amendments of required minimum hours of rest under the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) in 2010. Different marine staff follow different limits of work and rest.

4.3.4 Canada

Rail – Similar to the United States, Transport Canada is initiating amendments to the Canadian rail safety regulatory framework, which include amendments and additions to the current limited hours prescribed to operators. Transport Canada is currently undertaking a review on the best practice of applying a risk-based approach of fatigue management to support regulatory changes (ONRSR, 2018; Axxess International, 2018).

Commercial vehicles – Under the Motor Vehicle Transport Act, Transport Canada is responsible for the outer limits of service regulations. In 2004, Canada amended its limits of service for commercial vehicle drivers to 13 hours of driving and 14 hours of duty per 24 hours. This increased the minimum off-duty period from eight to 10 hours per 24 hours (Gander et al., 2011).

In addition to the regulated outer limits of service, Transport Canada also complements the fatigue management with other non-prescriptive programs that could be voluntarily adopted by operators (Transport Canada, 2016). These non-prescriptive programs include the Northern American Fatigue Management Program (NAFMP), which was scientifically developed guidelines and training sessions to help managers, drivers, dispatchers, and family members further understand and manage fatigue risk (Thiffault, 2011).

Aviation – In 2017, Transport Canada announced its proposal of a new fatigue management in the aviation industry. Two key aspects of the proposed change are the flexibility of operators using risk-based approaches approved by Transport Canada if they can demonstrate adequate levels of safety, and new scientific-based flight and duty time limits (Government of Canada, 2017). For example, an operator could be permitted to fly longer than the prescribed flight duty time limit if they can show that alertness and fatigue will not be affected, and that the operator meets the requirements of a risk-approach that is approved by Transport Canada (Government of Canada, 2017).

Maritime – The Canadian maritime industry follows various international conventions of limits to work and rest, such as the International Convention for the Safety of Life at Sea (SOLAS) and the ILO Maritime Labour Convention, 2006. Different vessel types in the Canadian maritime industry follow different limits of work and rest.

The Transport Safety Board of Canada is aware of the limitations to the current limits of work and rest. It is seeking to move towards a risk-based approach to manage fatigue, although it faces many challenges, including the subjective perception of fatigue – making fatigue difficult to measure.

5 Impact of outer limits of service

This chapter presents information on the current or potential costs of outer limits of service for train drivers for a number of rail operators around Australia. The total benefits related to national harmonisation of regulations (understood as bringing Queensland and NSW into line with the rest of Australia) have not been analysed because of the complexity and diversity of rail operations around Australia. Different operators are impacted by outer limits of service in different ways depending on the type of services they operate (and where they operate). The benefits of harmonisation in itself (for example, through reduced cost of understanding regulations in different states) have also not been analysed because they are outside the scope of the project.

Section 5.1 describes three broad ways in which outer limits of service can affect economics costs. Sections 5.2, 5.1, 5.4 and 5.5 present case studies relating to Aurizon, Pacific National, a major Pilbara mine operator and TasRail, respectively. Each case study below first describes the situation and how outer limits of service for train drivers currently impacts or if introduced, could impact efficient operational approaches. The cost in each of these categories are then presented. More detail on the calculation of costs is included in Appendix B.

The impacts have been calculated by Deloitte Access Economics using information provided by rail operators. The information has been provided in response to discussions and data requests relating to how their operations would differ with and without legislated outer limits of service for train drivers. This information has not been verified by Deloitte Access Economics. Publicly available information (for example, on the number of deaths per road kilometre travelled) have also been used where appropriate. Further detail on the approach to the modelling is set out in Appendix B.

The case studies included here are not exhaustive and do not cover the full range of ways that outer limits of service for train drivers in Queensland and NSW currently impact rail operators, or could potentially impact rail operators if introduced in other States. Rather, they present a range of examples of how changes to this regulation could affect the industry. The case studies have been selected based on availability of information.

5.1 Economic costs of outer limits of service

In each of the case studies below, costs are categorised into three broad groups, developed based on consultation with industry participants: staff costs, road transport costs, and capital costs.

- **Staff costs**
  By reducing the number of hours that employees can work in a shift, outer limits of service affect the way staff are rostered and how the workforce is managed. For example, to comply with outer limits of service additional workers are needed. This creates additional staff management challenges and additional requirements for training and recruitment of new staff. Outer limits of service also means that staff may be offered less appealing or less flexible working conditions. The total impact on staffing depends, in practice, on the interaction of a range of factors, including (for example) rest periods between shifts, enterprise agreements, and the spatial characteristics of impacted services. In jurisdictions with outer limits of service in place, these impacts have already occurred; while in other jurisdictions, they would occur if outer limits of service were introduced.

- **Additional transport costs**
  The heightened risk associated with increased use of road travel was a major concern expressed by many of those consulted. Time that rail employees spend on roads rates among the highest risks facing rail operators, and complying with outer limits of services can in some instances only be achieved through the use of road relief. Where this does have to occur, it may mean changing crews in less-than-ideal conditions. Ideally, train drivers begin and end shifts at their home depot (or undertake barracks working where necessary). Under outer limits of service, however, crew changes are forced to occur at other (non-preferred) points along the route, with fresh crew transported to the train by road and the relieved crew being transported back to their depot by road as well. This creates an increased likelihood of crashes causing fatalities, injuries and damage to property as well as increasing road vehicle operating costs.

- **Capital costs**
  Outer limits of service have the potential to increase capital costs for rail operators because of the need to invest in new depots or rolling stock (to increase the productivity of each service).

5.2 Impacts in the Blackwater Coal Rail System

The Blackwater Coal Rail System is the largest coal system in Aurizon's Central Queensland Coal Network. The system links mines from the Bowen Basin to the Port of Gladstone, Australia's third-largest coal terminal. This case study only applies to a small portion of the system and provides an example of how outer limits of service affect operations on the system.

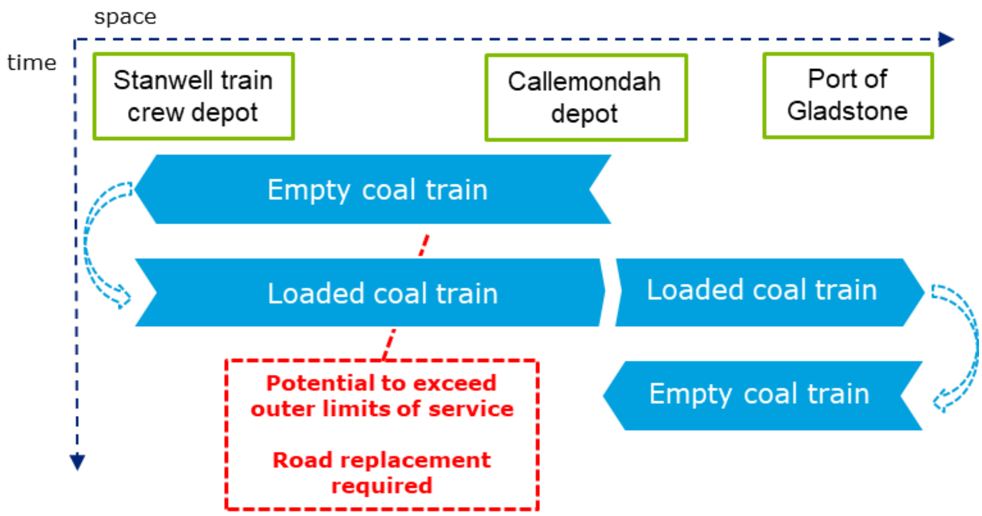
One of the shifts that Aurizon operates on this system involves two drivers operating an empty train from the Callemondah depot (located in Gladstone) to Stanwell depot, where they disembark and wait for a loaded train, which they then drive back to Callemondah, where their shift ends. At this point, a single driver takes over operation of the full train at Callemondah, and they drive it to the Port of Gladstone and back to Callemondah. This connected service is represented in Figure 5.1 below.

The timing of the arrival of loaded trains in Stanwell varies day to day, and progress along the trip back from Stanwell is not guaranteed. This makes it possible for train drivers' shifts to run over the current 12-hour limit for a two driver operation in Queensland (also in place within Aurizon's current Enterprise Agreement). To avoid this, Aurizon closely monitors its operations and transports fresh two-driver crews along the system between Callemondah and Stanwell, as necessary by road. Under legislated outer limits of service this has to occur no matter how close the train is to its final destination.

Aurizon has estimated that the round trip from Callemondah to Stanwell and back would approach or exceed 12 hours in duration around 20% of the time. Where this occurs, it would be illegal for the train drivers to continue operating under outer limits of service; so the train has to be stopped at a non-preferred location for a change of crew. This requires two fresh train drivers to be transported to the train via the road network, and the over-hours drivers would be driven back to the Callemondah depot by road (they cannot drive themselves under the laws). Figure 5.1 (see below) sets out this scenario.

When road relief has to occur, fresh drivers may drive themselves out to the train, with the crew previously driving the train then travelling on road back to Callemondah. Time spent driving on road, however, counts towards shift length calculations, as additional staff may be required to escort train drivers to and from the trains along the route.

Figure 5.1 Part of the Blackwater Coal Rail System



The introduction of additional road travel generally increases a task's risk profile than allowing drivers to complete their shift, for two reasons. Firstly, it involves transferring staff from the relatively controlled environment of the rail system to the relatively uncontrolled environment of the public road system. Secondly, it involves crew changes occurring at locations that are less desirable from a safety and accessibility perspective (compared to the home depot).

The impacts of Queensland's current outer limits of service come principally in the form of over-time paid to workers in order to manage crew relief where shifts would exceed outer limits of service. An important cost is the initial cost of relieving crew, through road travel, which includes road vehicle operating costs and road externalities. These initial changes then have flow-on effects for staffing other services as crews must be shuffled between different tasks. The annual value of these costs is:

- **Additional wages of staff associated with road relief ($283,000 annually).**
  - It is estimated that, each year, the initial road relief and flow on effects for staff time amount to an additional 4,380 hours of work being undertaken. At an industry average cost per hour worked of around $65, this gives a total annual cost of around $283,000. This hourly cost includes wages as well as administrative costs paid by the business to manage the worker (such as additional taxes).
- **Road vehicle operating costs ($221,000 annually).**
  - The road relief operations result in a total of around 350,000 additional vehicle kilometres travelled per year in road vehicles. The type of vehicles used in this operation cost around 63 cents per kilometre, resulting in total costs of around $221,000 each year.
- **Externalities associated with road vehicle use ($63,000 annually).**
  - Each of the additional 350,000 vehicle kilometres travelled creates externalities in terms of increased crash costs (including deaths and injuries), air pollution, greenhouse gas and noise. These costs total around 18 cents per vehicle kilometre. This gives a total externality cost of around $63,000 per year.

The total annual value of these costs on Aurizon's Blackwater Coal Rail System is around $567,000. The net present value (NPV) of these costs over a 30-year period is $7.0 million.[5] This is a compliance cost that reduces productivity. This cost must be worn by the operator or passed onto the customer. As these costs only apply to parts of the network, the overall costs of compliance to outer limits of service on the Blackwater Coal Rail System are likely to be higher.

[5] NPVs throughout the report used a 7% discount rate.

5.3 Impacts in the Goonyella Coal Rail System

The Goonyella Coal Rail System is a large coal system in Aurizon's Central Queensland Coal Network. The system links mines from the Bowen Basin to coal terminals at Dalrymple Bay and Hay Point. In operating in the Goonyella system, Pacific National seeks to minimise train driver car travel and 'barracks working' and maximise train driver driving time. This case study only applies to a small portion of the system and exemplifies how outer limits of service affect operations on the system.

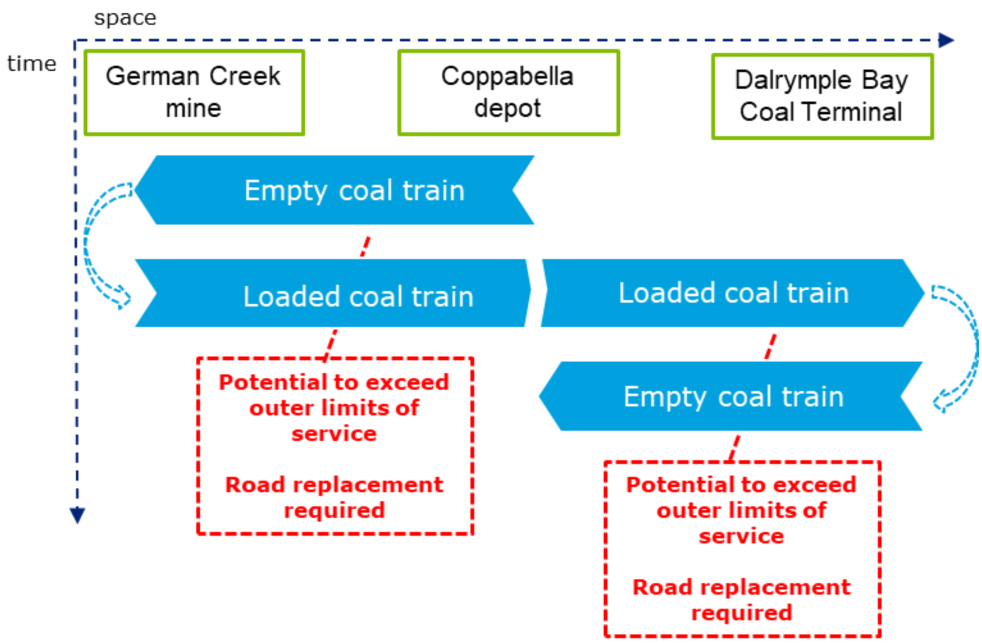
Among various coal hauls, Pacific National hauls coal from German Creek mine to Dalrymple Bay Coal Terminal (DBCT). To do this, two drivers board an empty coal train at Coppabella depot (approximately mid-way between German Creek and DBCT), travel to German Creek, load and then return to Coppabella. At Coppabella depot, these drivers will end their shift. The planned length of this shift is 9.25 hours. At this point, two new drivers board the loaded train, drive it to DBCT, unload the train, and then return to Coppabella. The planned length of this shift is 11.25 hours. This system is shown in Figure 5.2 below.

Pacific National has estimated that this service is able to be completed within the 12 hour outer limit of service around 60% of the time. On the remaining 40% of services, crew changes have to be done via the road network. Pacific National manages its operations to allow train drivers to drive road vehicles to and from trains that would exceed the outer limits of service.

This increases risk to crew due to the increased time spent on road and crew changes in non-preferred locations. It also increases costs and operational complexity for the rail operator.

Pacific National has estimated that this situation results in five additional train drivers being employed to deliver this service over and above what would be the case if the outer limits of service were not in place.

Figure 5.2 Goonyella Coal Rail System



The impacts of Queensland's current outer limits of service come principally in the form of the additional staff that are needed to cover the possibility of shifts exceeding outer limits of service, but also include road vehicle operating costs and road externalities. Their annual value is as follows:

- **Costs of employing additional train drivers (including on-costs) ($722,000 annually).**
  - It is estimated that, each year there would be a requirement for an additional 5 Full Time Equivalent (FTE) workers. At a location specific average cost per FTE of around $144,000 gives a total annual cost of around $722,000. This cost per FTE includes wages as well as administrative costs paid by the business to manage the worker (such as additional taxes).
- **Road vehicle operating costs ($81,000 annually).**
  - The road relief operations result in a total of around 128,000 additional vehicle kilometres travelled per year in road vehicles. The type of vehicles used in this operation cost around 63 cents per kilometre, resulting in total costs of around $81,000 each year.
- **Externalities associated with road vehicle use ($23,000 annually).**
  - Each of the additional 128,000 vehicle kilometres travelled creates externalities in terms of increased crash costs (including deaths and injuries), air pollution, greenhouse gas and noise. These costs total around 18 cents per vehicle kilometre. This gives a total externality cost of around $23,000 per year.

The total annual value of these compliance costs is around $826,000. The net present value (NPV) of these costs over a 30-year period is $10.2 million.

The time and cost associated with training the additional train drivers employed to maintain compliance with Queensland's outer limits of service have not been included in the above figures.

As these costs only apply to parts of the network, the overall costs of compliance to outer limits of service on the entire Goonyella Rail System are likely to be higher. In particular, Pacific National serves at least 12 mines in the Goonyella system and while the costs of fatigue management would vary, depending on the mine location and the number of train services, the costs identified in this case study are only a small portion of the total costs of outer limits of service in the Goonyella system.

5.4 Potential impacts on a major Pilbara mine operator

This Pilbara mine operator case study employs around 450 train drivers involved in the transport of iron ore from various mines to ports in the Pilbara region of Western Australia.

Currently, train drivers work 12-hour shifts that involve driving loaded and unloaded trains back and forth on a portion of track between mines and the port. For example, one driver may drive an unloaded train south from the port, hop off that train, and drive a loaded train back to the port.

In that 12-hour shift, there is typically around an hour of time spent undertaking paper work, attending pre work safety meetings and other essential aspects of their role. The remainder of the shift is spent operating a locomotive.

If outer limits of service for train drivers were introduced in the Pilbara, two strategies could conceivably be pursued:

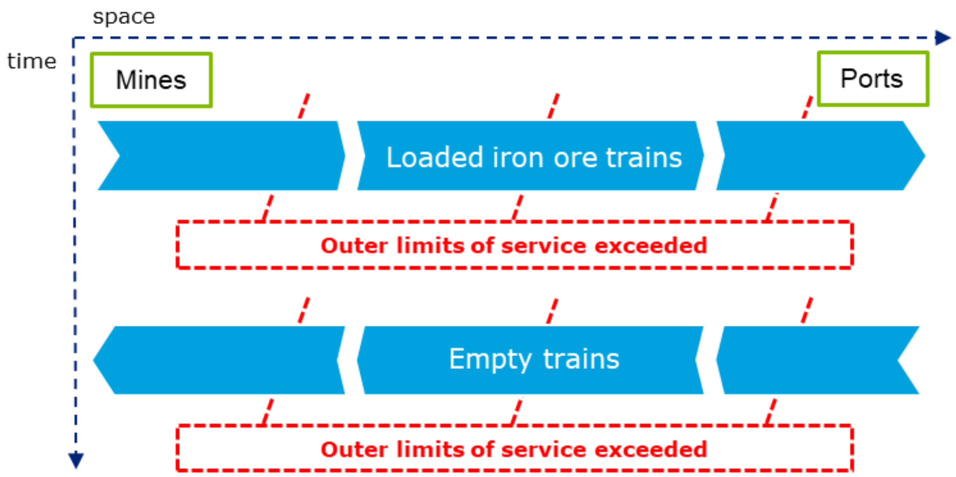
- employ additional drivers and invest in a new depot along the rail line at which drivers could start and finish shifts (due to area remoteness); or
- employ additional drivers and transport drivers to and from trains along the railway by road as they approach the outer limits of service.

The operator has indicated that the second strategy would not be feasible for safety reasons. Road accidents, often involving collisions between animals and vehicles, are a major risk to personnel safety in the rural environment in which these rail services operate. If road relief was used instead of building a new depot it would likely involve in the order of an additional 200,000 kilometres of road travel, on mostly poor quality surfaces each year. Public roads only intersect the rail line in a few locations, so there is a reliance on locally constructed service tracks. In addition, seasonal weather events (monsoonal rain and cyclones) often impact the ability to utilise these tracks for weeks at a time, making this approach unworkable for months of the year during monsoon season.

It would be necessary to employ additional train drivers because outer limits of service similar to what is currently legislated in Queensland or NSW would fundamentally change how much work a given number of employees can do. Currently, two employees can do 22 hours of driving in a 24-hour period (the 12 hour shift, less an hour of time spent not driving). If they could only do 9-hour shifts, 2.75 employees would be needed to do the same amount of driving in a 24-hour period.

Based on these changes, it is estimated that 225 additional train drivers would be needed to maintain current levels of operations, a 50% increase on the operator's 450 train drivers currently employed.

Figure 5.3 A major Pilbara iron ore miner and rail operator



To continue operating at current levels, the potential cost of complying with outer limits of service akin to what is used in Queensland or NSW would come in the form of staff costs and capital costs (and the operating and maintenance costs of that capital). These are estimated as follows:

- **Costs of employing 225 additional train drivers (including on-costs) ($50.4 million annually);**
  - It is estimated that, each year there would be a requirement for an additional 225 FTE workers. At a location specific average cost per FTE of around $224,000, this gives a total annual cost of around $50.4 million. This cost per FTE includes wages as well as administrative costs paid by the business to manage the worker. In particular, this includes base salary, FIFO allowance, superannuation, flight assistance, bonuses and other special awards.
- **Capital costs of a new depot and accommodation facilities are estimated to be $10 million, and ongoing operating costs are assumed to be 3% of this value ($300,000)**

The total annual value of these compliance costs is around $50.7 million annually. The net present value (NPV) of these costs over a 30-year period is $640 million.[6] These costs do not factor in the additional time taken to train new staff, or the fact that staff would need to be paid while not being fully trained (potentially for up to 24 months).

These costs assume that additional workers can be recruited and retained under current wages. In reality, this may be difficult because the current rostering and wage agreements are predicated on the operator's ability to operate 12-hour driver-only shifts. Changes to this may affect the wage

[6] NPVs throughout the report have been calculated using a 7% discount rate.

and work conditions that can be offered, potentially affecting the ability to recruit and retain staff in the Pilbara. For example, many rail workers in the Pilbara live in locations around Australia, New Zealand and Asia with the rostering approach around 12-hour shifts being an appealing part of the work. If this rostering approach was changed, these workers may not find work in the Pilbara as attractive.

Building a new depot would also require appropriately managing potential environmental, cultural and heritage impacts, given the location of the rail line. These have not been included in the figures provided above.

An additional cost that has not been included in the calculations is the increase of train cycle time associated with decelerating, exchanging safety critical information and crew and then accelerating back to speed. In total, this results in a roughly 4% reduction in effective operating time each day. This additional cycle time has a direct impact on productivity and is likely to affect the competitiveness of Australia's iron ore exports. The operator has estimated that export volumes could potentially be reduced by 35 million tonnes of iron ore in a single year for all Pilbara operators under this scenario and if mitigating productivity improvements weren't achieved. At July 2018 prices this would equate to delays in the delivery of trade worth in the order of $2.4 billion. This would not be a net loss to the economy overall but would mean that revenue from sales of this iron ore would be realised later, reducing its current value to the economy.

Each crew change also creates additional wear and tear on trains and maintenance and fuel costs could be significantly increased by the need to accelerate the train additional times. In the supply chain for an internationally traded commodity, these costs could affect the competitiveness of Australian businesses and ultimately, impact the Australian economy.

5.5 Potential impacts on TasRail

TasRail, the government owned business that handles all of Tasmania's rail freight needs, would be impacted by the introduction of outer limits of service. All of TasRail's services are driver only at present, and a number of these services currently have shift lengths greater than either the current NSW or Queensland outer limits of service.

TasRail has estimated how its operations could be affected if 9 hour shifts with 15 minutes fatigue breaks were introduced. These estimates assume that no exemption is sought or granted to operate outside the hypothetical outer limits of service.

Estimates have been produced for impacts on the Melba line, TasRail's service freighting cement from Railton to Devonport, and in the main line services.

On TasRail's Melba line, which connects Burnie and Melba Flats, there are regular shifts of 10.5 and 11 hours. With 9 hour shifts, a likely alternative would be to operate the service using three 9 hour shifts, implying an increase in person-hours per trip of 5.5 hours. Assuming four trips per week, this equates to 22 extra hours per week, which would likely need to be resourced through the recruitment of an additional FTE driver.

TasRail has a contract with Cement Australia at Railton for the transport of cement to Devonport, where the cement is then transported by ship. This involves the transport of around 1.35 million tonnes of cement annually, and the contract is serviced by nine FTEs at present who typically work 12.5-hour shifts. TasRail has estimated that moving to nine-hour shifts would create a need to hire an additional driver. This is based on the amount of paid time needed to accomplish the same amount of work as previously (taking into account additional shift changes and so on) increasing by 23 hours per week.

TasRail is contracted to provide a service every four hours for Cement Australia per day. This would be impacted if outer limits were introduced. TasRail has estimated that there would be a loss of productive time in its Cement Australia operations (a loss of roughly 30 minutes per cycle, reducing the number of cycles possible per week from 42 to 37). TasRail considers that this loss in number of trains would likely need to be addressed through providing a longer, heavier train each cycle. This would require investment in additional capital (an extra two wagons, a DQ locomotive, and extending existing rail sidings and boundary fencing). TasRail has estimated the total cost of this capital investment at $7,000,000.

Throughout its main line services (including operations linking Burnie and Hobart – Tasmania's main freight corridor), TasRail has estimated that compliance with outer limits of service would increase staffing requirements by 4 FTEs. These additional drivers would be located in different depots around the state.

Across these three areas – the Melba Line, the Cement Australia contract, and the mainline services – TasRail has estimated that outer limits of service involving maximum nine-hour driver only shifts would require the recruitment of around six additional FTE drivers and one additional rail operator.

In total, these costs are estimated as follows:

- **Costs of employing additional train drivers (including on-costs) ($8.7 million annually);**
  - At an average wage of $80,000 per year for drivers, and $57,200 for the rail operator, and assuming that on-costs for employees amount to 30% of their wage (this includes training, tools, safety gear, etc.), the additional wage bill would amount to $698,360 annually.
- **Capital costs of extra wagons, locomotives and supporting facilities of ($7 million)**

The total annual value of these compliance costs is around $698,000. The net present value (NPV) of these costs over a 30-year period is $15.7 million.

The potential impact on the competitiveness of TasRail's services and available road freight alternatives has not been factored into the above analysis. At the distances involved, moving freight throughout Tasmania on rail competes directly with road.

Over recent years, TasRail and Tasmanian State Government investments in rolling stock and rail infrastructure have resulted in a rail freight system that provides services of comparable price and quality to what is available on road.

The potential cost increases noted above would need to be recovered through efficiencies or price increases, potentially resulting in some freight moving to the road system. This would have a net increase on congestion, emissions, and the risk of road incidents – creating costs for the Tasmanian community at large. Price increases for rail users may also be passed through to consumers or affect the competitiveness of the company using rail. Research conducted by ACIL Allen for the Tasmanian Department of State Growth found that rail price increases of 20% would potentially result in all freight moving onto road in the Burnie to Hobart Freight Corridor (ACIL Allen, 2017).

At the same time, there are some identifiable limitations to substitutability and loss or change to current rail services could adversely affect downstream businesses. For example, the road network in western Tasmania would potentially have difficulties providing the iron ore mine at Rosebery with the same level of service as TasRail currently does, and transporting cement between Railton and Devonport would be similarly difficult. Where substitution is possible it would likely involve certain transition costs (as businesses need to reconfigure supply and freight needs to align with what is possible on road). This may also result in the need for significant investment in road improvements or maintenance. These are only two examples of particular businesses that may face difficulties substituting road for rail freight.

Conclusion

Overall, this report finds that outer limits of service currently impose costs on the Australian economy and that further extension of outer limits of service has the potential to increase costs for rail operators across the country. Outer limits of service reduce rail operators’ flexibility to efficiently run their business, both within a state and also across state borders.

In the face of these costs, there does not appear to be evidence that outer limits of service for train drivers improves fatigue management relative to risk-based approaches. Outer limits of service can also reduce safety for train drivers and the community, particularly where the use of road travel increases. Movements towards applying outer limits of service is also counter to trends seen across the transport industry.

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Appendix A: Outer limits details

Table A.1 Outer limits of service for train drivers in NSW and Queensland

Configuration Type	Variation
Freight train – Single driver	• Queensland has no prescribed breaks • NSW has a minimum prescribed break period of not less 30 minutes between the third and fifth hour of each shift.
Freight train – Two persons	• NSW delineates the maximum shift length hours as: – 12 hours where the second driver is a qualified train driver (including a qualified train driver who is learning a route or undergoing an assessment); and – 11 hours in the case of any other two-person operation. • Qld only has a maximum 12-hour shift length where the second driver is a qualified train driver (including a qualified train driver who is learning a route or undergoing an assessment)
Freight train – All rail safety workers driving freight trains	NSW has one hour less of a prescribed break (hours to be continuous hours) between each shift where: • Shift ends at home depot (11 hours for NSW, and 12 hours for Queensland) • Shift ends away from the home depot and the break is taken away from the home depot (7 hours for NSW, and 8 hours for Queensland) In any 14-day period, both NSW and Qld have a prescribed maximum of 12 shifts. However, NSW prescribes that not more than 6 of those shifts are to be 12 hours whereas in Qld there is a limit of 132 hours of work within the 12 shifts.
Passenger train – Single	• For suburban services, NSW and Qld both have the same prescribed maximum shift length of 9 hours but Qld drivers can only drive for 8 hours at a maximum. • The maximum shift length in NSW for interurban or long distance services is 10 hours whereas 'any other passenger train' in Qld (that is not suburban) the maximum shift length is 9 hours (with no limit on driving time). A one-hour difference. • As per freight train drivers, Qld has a 1 hour longer (continuous) break between each shift where work ends both at the home depot or away (12 hours at home and 8 hours away) versus NSW (11 hours at home depot and 7 hours away). • In a 14-day period, NSW and Qld both have a maximum of 12 shifts but Qld prescribes a maximum amount of work hours of 132. NSW does not prescribe a maximum amount of work hours.
Passenger train – Two persons	NSW delineates the maximum shift length hours as: • 12 hours where the second driver is a qualified train driver (including a qualified train driver who is learning a route or undergoing an assessment); and

Configuration Type	Variation
	• 11 hours in the case of any other two-person operation. Queensland only has a maximum 12-hour shift length where the second driver is a qualified train driver (including a qualified train driver who is learning a route or undergoing an assessment).
Passenger train – All rail safety workers driving passenger trains	NSW has one less hour of a prescribed break (hours to be continuous hours) between each shift where: • Shift ends at home depot (11 hours for NSW, and 12 hours for Queensland) • Shift ends away from the home depot and the break is taken away from the home depot (7 hours for NSW, and 8 hours for Queensland) In any 14-day period, both NSW and Qld have a prescribed maximum of 12 shifts. However, NSW prescribes that not more than 6 of those shifts are to be 12 hours whereas in Qld there is a limit of 132 hours of work within the 12 shifts.
Train drivers who are transported to home depot or rest place	Similar provisions in NSW and Queensland
Emergencies and accidents	No variations

Source: ONRSR, 2018

Table A.2 Outer limits of service for road transport in the US

Property-carrying drivers	Passenger-carrying drivers
11-Hour Driving Limit May drive a maximum of 11 hours after 10 consecutive hours off duty.	10-Hour Driving Limit May drive a maximum of 10 hours after eight consecutive hours off duty.
14-Hour Limit May not drive beyond the 14th consecutive hour after coming on duty, following 10 consecutive hours off duty. Off-duty time does not extend the 14-hour period.	15-Hour Limit May not drive after having been on duty for 15 hours, following 8 consecutive hours off duty. Off-duty time is not included in the 15-hour period.
60/70-Hour Limit May not drive after 60/70 hours on duty in 7/8 consecutive days. A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off duty.	60/70-Hour Limit May not drive after 60/70 hours on duty in seven or eight consecutive days.
Sleeper Berth Provision Drivers using the sleeper berth provision must take at least 8 consecutive hours in the sleeper berth, plus a separate 2 consecutive hours in either the sleeper berth, off duty, or any combination of the two.	Sleeper Berth Provision Drivers using a sleeper berth must take at least eight hours in the sleeper berth, and may split the sleeper berth time into two periods provided neither is less than two hours.
Rest Breaks May drive only if eight hours or less have passed since end of driver's last off-duty or sleeper berth period of at least 30 minutes. Does not apply to drivers with short-haul exceptions.	

Source: https://www.fmcsa.dot.gov/regulations/hours-service/summary-hours-service-regulations

Appendix B: Modelling details

B.1. Modelling details

B.1.1. Global Parameters

The global parameters are the key assumptions applied for across each case study. For the modelling, the following assumptions are in detail below:

- Discount rate of 7%, under the guidance of the Australian Office of Practice Regulation (OBPR).
- Train drivers have 365 work days each year.
- Assume each train driver is mandated to follow eight hours of work for each working day, as each case study would following different regulations in practice.
- The operating and maintenance (O&M) cost is 3% of the accommodation capital cost, assuming a 40-year asset life and maintenance to maintain the book value of an accommodation asset, under Transport for NSW's *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*.
- Drivers are paid $50 per hour, in accordance to Glassdoor's *Train Driver Salaries* (unless specific wage rates have been supplied by operators in each case study).
- Total road externality cost of 18 cents per kilometre, in accordance to the externality unit costs for freight vehicles under Transport for NSW's *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*. The road externality costs comprise of: air pollution costing 0.03 cents/km; greenhouse gas emissions (GHG) costing 2.49 cents/km; water pollution costing 0.05 cents/km, nature and landscape externalities costing 0.58 cents/km; and upstream and downstream costs of 4.25 cents/km (and zero cost of noise externalities). The road externalities of costs are 11 cents/km, under the crash costs from road and passenger transport in Australia by Deloitte Access Economics.

B.1.2. Case study assumptions

With the global and case study assumptions, the additional costs of following outer limits of service were calculated.

Staff costs

The total staff costs include ongoing and new staff, and both involve wage and training costs.

Existing staff costs

The existing staff wage costs are totalled as:

$$Total\ existing\ staff\ cost = total\ working\ hours\ \times\ driver\ pay\ rate\ (assumed\ as\ \$50\ per\ hour)$$

With the total working hours for each case study are calculated as:

$$Total\ working\ hours\ per\ year = total\ number\ of\ drivers\ \times\ hours\ per\ driver\ (per\ year)$$

And the hours per driver (per year) is calculated as:

$$\begin{aligned} Hours\ per\ driver\ (per\ year) \\ &= hours\ per\ day\ (not\ under\ outer\ limits\ of\ service) \\ &\times\ work\ days\ per\ year\ (assumed\ as\ 365\ days\ per\ year) \\ &\times\ percentage\ of\ work\ days\ and\ off\ days \end{aligned}$$

New staff costs

The total cost of new staff wages under the outer limits of service (OLoS) is given under the following formulae:

$$\begin{aligned} Total\ new\ staff\ cost\ (under\ OLoS) \\ &= total\ drivers\ required\ under\ OLoS\ \times\ driver\ pay\ rate\ (assumed\ as\ \$50\ per\ hour) \\ &\times\ hours\ per\ driver\ per\ year \end{aligned}$$

- The total drivers required under OLoS are calculated as the total working hours of existing staff (calculated in the previous section) divided by the total hours per driver under OLoS. The total hours per driver under OLoS are calculated as:

$$\begin{aligned}&Total\ hours\ per\ driver\ under\ OLoS\\&\quad = mandated\ hours\ per\ day\ (assumed\ as\ 8\ hours)\\&\quad \times work\ days\ per\ year (assumed\ as\ 365\ days\ per\ year)\\&\quad \times percentage\ of\ work\ days\ and\ off\ days\end{aligned}$$

The hours per driver (per year) is given as:

$$\begin{aligned}&Hours\ per\ driver\ per\ year = work\ hours\ per\ day \times percentage\ of\ work\ days\ and\ off\ days \times\\&work\ days\ per\ year\ (assumed\ as\ 365\ work\ days\ per\ year)\end{aligned}$$

Vehicle costs
Additional vehicle costs include the total on-road vehicle operating costs (VOC) per year and the total additional costs for on-road externalities per year.

Note that the number of round trip rail journeys per year is calculated as:

$$Number\ of\ round\ trip\ journeys\ by\ rail = total\ working\ staff\ hours \div (round\ trip\ time \times crew\ per\ journey)$$

Total additional VOC per year
The on-road operating costs are calculated by using the formulae below:

$$Total\ opeating\ cost\ on\ road = total\ number\ of\ road\ trips \times VOC\ per\ road\ trip$$

- The total number of road trips is given by:

$$Total\ number\ of\ road\ trips = road\ trips\ per\ round\ trip\ by\ rail \times total\ number\ of\ rail\ trips$$

- And the VOC per road trip is given by:

$$VOC\ per\ road\ trip = VOC\ per\ kilometre \times kilometres\ per\ road\ trip$$

Total additional road externalities per year
The additional road externalities (per year) are calculating using the following formula:

$$\begin{aligned}&Total\ externality\ cost\ on\ road\ per\ year\\&\quad = total\ cost\ of\ road\ externalities\ per\ kilometre \times kilometres\ per\ road\ trip\\&\quad \times number\ of\ road\ trips\ per\ year\end{aligned}$$

Fatalities and injuries
The potential increase in road crashes is based on the additional road kilometres travelled, which are calculated as:

$$\begin{aligned}&Additional\ road\ kilometres\ travelled\ per\ year\\&\quad = Drivers\ per\ rail\ journey \times kilometres\ per\ road\ trip\\&\quad \times Total\ number\ of\ road\ trips\ per\ year\end{aligned}$$

From the calculated additional road kilometres travelled, the potential additional fatalities and major injuries per year are calculated by multiplying their corresponding ratios per billion kilometres:

$$\begin{aligned}&Potential\ fatalities\ per\ year\\&\quad = Additional\ road\ kilometres\ travelled\ per\ year\\&\quad \div (fatality\ rate\ per\ billion\ kilometres \times 10^9)\end{aligned}$$

$$\begin{aligned}&Potential\ major\ injuries\ per\ year\\&\quad = Additional\ road\ kilometres\ travelled\ per\ year\\&\quad \div (serious\ injuries\ rate\ per\ billion\ kilometres \times 10^9)\end{aligned}$$

Limitation of our work

General use restriction

This report is prepared for the use of the Australasian Railway Association. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of analysing the economic costs associated with outer limits of service. You should not refer to or use our name or the advice for any other purpose

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