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BUREAU OF INFRASTRUCTURE AND TRANSPORT RESEARCH ECONOMICS

Road and Rail Supply Chain Resilience Review – Phase 1

Building an evidence base of road and rail supply chain resilience

February 2023

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Foreword

All Australians depend on resilient supply chains. The impacts of COVID-19, natural disasters and a growing freight task have shown the increasing importance of domestic on-land supply chains to the national economy and the lives of Australians. Identifying and understanding critical supply chains, the risks they face, and how government and industry can work to mitigate these risks is essential to ensure supply chains remain resilient and fit-for-purpose, now and in the future.

This report presents the Bureau of Infrastructure and Transport Research Economics' (BITRE) findings from an initial assessment of Australia's road and rail supply chain resilience, to help inform action by government to effectively and efficiently mitigate or address risks to critical road and rail supply chains for the benefit of all Australians.

The evidence in this report draws on a literature review, extensive stakeholder consultation and geospatial analysis, including scenario modelling. Scenario modelling provides greater insight into a number of key critical and vulnerable routes, including an assessment of the likelihood and expected impact of various hazards on road and rail supply chains. The Review also presents a number of case studies to provide real-world illustrations of the impact of natural and human induced risks, as well as examples of initiatives to address supply chain issues.

This report has been prepared by Leo Soames, Nathan Naicker, Michelle Xu, Liana Levin and Harry Grant.

BITRE acknowledges the support provided by the Freight Industry Review Panel (John Fullerton, Nicole Lockwood, Brett Charlton, Sophie Finemore and Andrea Staines OAM), who provided expert advice throughout the work of the Review.

Shona Rosengren

Head of Bureau
BITRE
February 2023

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Executive summary

As domestic freight demands continue to grow and evolve, Australians now more than ever depend on efficient and reliable supply chains. Recent events such as flooding, bushfires and the COVID-19 pandemic have highlighted the importance of resilient supply chains in times of crisis. The Road and Rail Supply Chain Resilience Review (the 'Review') aims to identify and analyse Australia's critical road and rail freight routes and the risks they face, including identifying current resilience initiatives which are addressing these risks.

The Review has found that, while Australian road and rail supply chains have been flexible and adaptable in response to disasters, there are ways to lift resilience in the face of changing risks. The Review has identified and assessed the vulnerability of Australia's critical supply chain routes, the key risks that impact these routes, and existing initiatives that aim to lift resilience.

The Review utilises CSIRO's Transport Network Strategic Investment Tool (TraNSIT) to identify and assess 52 critical road and 13 critical rail supply chains from the National Key Freight Routes (KFRs) to develop a better understanding of Australia's road and rail resilience. The critical routes (critical KFRs) were selected for assessment based on the following criteria:

Road:

- 44 KFRs were selected due to high overall volume use, value and proportion of essential commodities. To ensure that each jurisdiction was represented, a minimum of the top two KFRs based on the high-use criteria were included for each state and territory.
- 8 KFRs were selected where Local Government Areas (LGAs) are dependent on that freight route for supply or a pathway to markets.

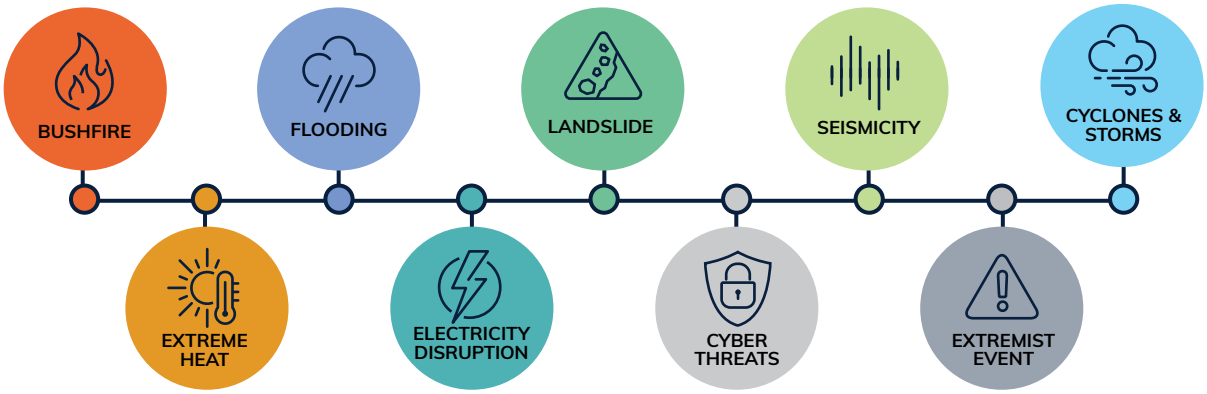
Rail:

- 13 KFRs were selected based on the diversity of their commodities and freight volumes, with a preference on routes connecting major centres.

These selected critical KFRs represent the most critical supply chain routes in Australia. Each critical KFR identified has undergone modelled 'closures' to evaluate the impacts of disruption on freight flows, costs and communities. The scenario modelling replicates the impact of disasters disrupting these routes and demonstrates how freight movements may respond to these closures, by either being re-routed where possible, or identifying where re-routing is impossible or at very high costs.

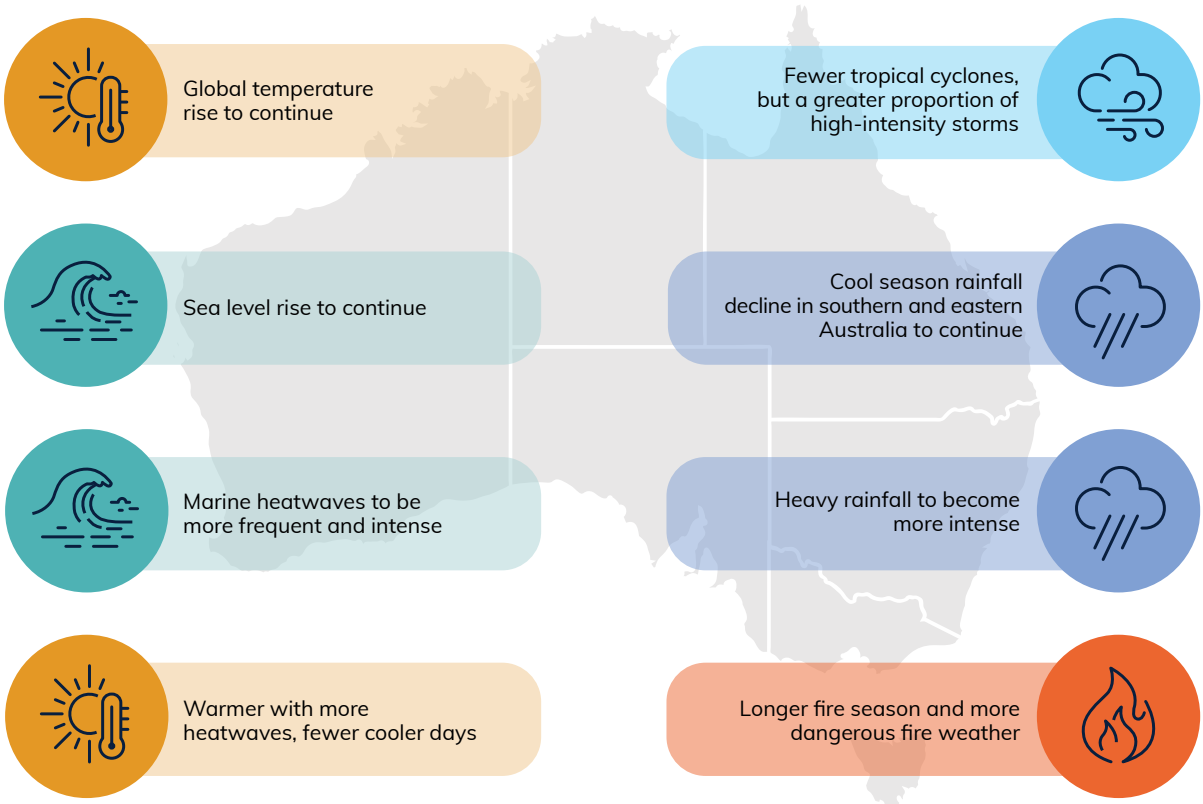
The Review considered current state and territory emergency risk assessments to identify and analyse the key risks that impact Australia's road and rail supply chain infrastructure (Figure 1), and applied a risk framework to assess and better understand the vulnerability of the identified critical KFRs. A vulnerability rating was calculated for each modelled closure by considering the likelihood and consequence of each key risk, the adaptability of the critical route in response to disruption, and the potential cost and community impacts.

Figure 1. Key risks to road and rail supply chain infrastructure



The Review acknowledges risk profiles for road and rail supply chains are changing and will continue to do so in the future. Risk levels that were once (or currently) considered acceptable, including strategies to address these risks, will need to adapt to accommodate these changes. For example, a number of key risks are forecast to increase in severity and frequency due to a changing climate (Figure 2). Similarly, the advancement of technology and digital connectivity is seeing increasing trends of human induced risks such as cyber-related disruptions. The impacts from these emerging trends will need to be accounted for to ensure Australia's road and rail supply chains remain resilient.

Figure 2. Australia's changing climate



Source: State of the Climate 2020 (Bureau of Meteorology n.d.)

Critical KFRs identified as most vulnerable

The Review applies a risk framework to calculate an overall vulnerability rating (ranging from 'very low' to 'very high') for each critical KFR to understand the impact of disruptions. A 'very high' vulnerability rating is defined as a critical KFR with a very high risk of natural hazard disruption, in which a disruption would result in a very high proportion of freight obstructed or a very high impact on alternate road routes (in the case of modal shift from rail to road). Of the 65 critical KFRs assessed (road and rail), the Review has identified the following routes as the most vulnerable (see Figure 3 and Figure 4).

Figure 3. Critical road KFRs with high and very high vulnerability ratings

Arnhem Highway: Vulnerability rating: Very High

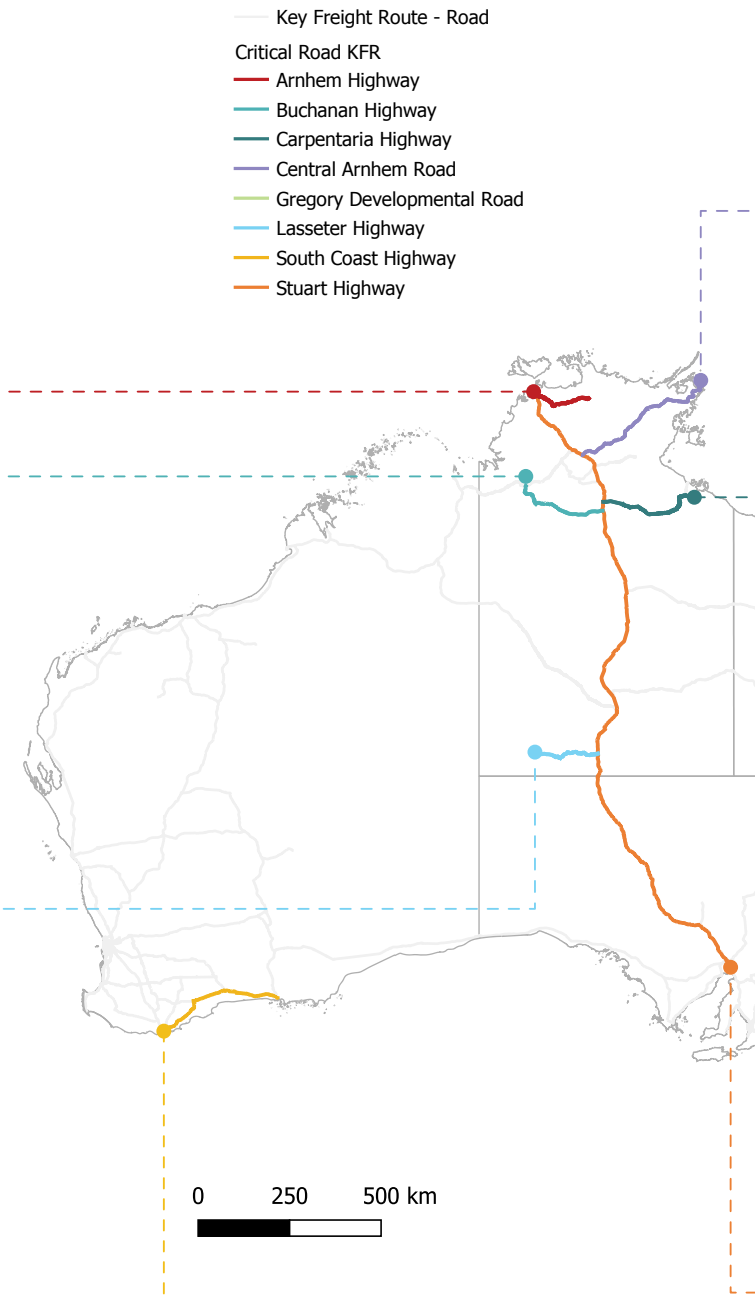
The Northern Territory's 224km Arnhem Highway connects Darwin to northwestern LGAs. Construction transport represents 55 per cent of the total freight task. Importantly, the KFR supports the movement of processed food and fuel to communities, and cropping and livestock to and from enterprises. The KFR passes through three LGAs and supports supply chain paths for over 59 LGAs. The three intersections assessed are primarily exposed to cyclones and storms, flooding and bushfires. At the Point Stuart Road and Oenpelli Road intersections, disruptions can result in 100 and 98 per cent of freight respectively completely obstructed.

Buchanan Highway: Vulnerability rating: High

The Northern Territory's 395km Buchanan Highway connects the Stuart Highway to the Victoria Highway. Livestock transport represents 60 per cent of the total freight task, with construction the only other significant freight along the route. The KFR passes through three LGAs and supports supply chain paths for over 50 LGAs. The three intersections assessed are primarily exposed to cyclones and storms and extreme heat. At the Buntine Highway and Victoria Highway intersections, disruptions can result in 80 and 99 per cent of freight respectively completely obstructed.

Lasseter Highway: Vulnerability rating: High

The Northern Territory's 245km Lasseter Highway connects LGAs from the Stuart Highway west to Yulara. Fuel transport represents 50 per cent of the total freight task, with the majority of movements from depots to stations. Livestock represents 30 per cent to the total freight task. Importantly, movements to supermarkets (including processed food and general freight) adds 10 per cent to the total freight task. The KFR passes through two LGAs and supports supply chain paths for over 38 LGAs. The three intersections assessed are primarily exposed to flooding and extreme heat. At the Mulga Park Road intersection, disruptions can result in 98 per cent of freight completely obstructed.

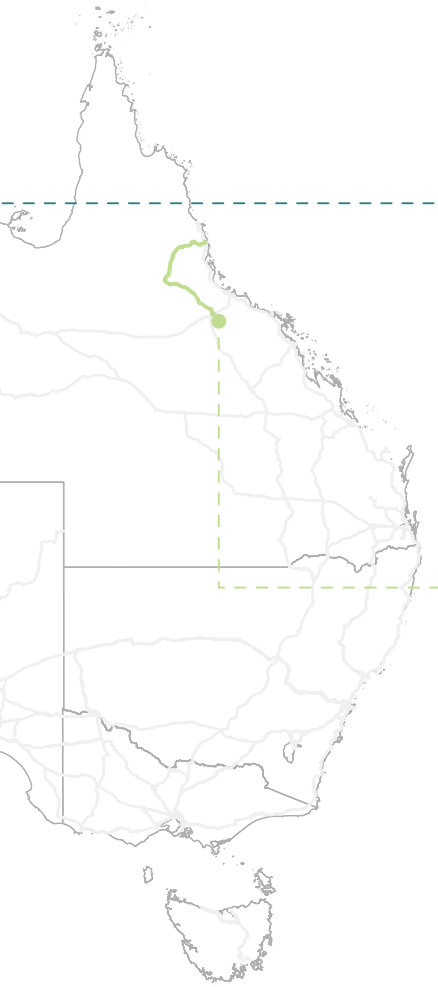


South Coast Highway: Vulnerability rating: High

Western Australia's 467km South Coast Highway connects LGAs from Albany to Esperance. Cropping transport represents 80 per cent of the total freight task, with a large proportion of movements from properties to silos and on to ports. Wood products represent 10 per cent of the total freight task, with a large proportion of movements to ports. The KFR passes through four LGAs and supports supply chain paths for over 181 LGAs. The three intersections assessed are primarily exposed to flooding and seismicity. At the Harbour Road intersection, disruptions can result in 100 per cent of freight completely obstructed.

Central Arnhem Road: Vulnerability rating: High

The Northern Territory's 675km Central Arnhem Road connects LGAs between the Stuart Highway and Nhulunbuy in the northeast. Construction transport and livestock represent 50 and 12 per cent of the total freight task respectively. Processed food and fuel represent 10 per cent of the total freight task. The KFR passes through five LGAs and supports supply chain paths for over 34 LGAs. The one intersection assessed (at the Stuart Highway) is primarily exposed to cyclones and storms and bushfires, and disruptions can result in 100 per cent of freight completely obstructed.



Carpentaria Highway: Vulnerability rating: High

The Northern Territory's 367km Carpentaria Highway connects LGAs between the Gulf of Carpentaria to the Stuart Highway. Fuel transport represents 75 per cent of the total freight task, with critical links from ports to depots and mines. Livestock and mining represent 20 per cent of the total freight task. The KFR passes through two LGAs and supports supply chain paths for over 48 LGAs. The two intersections assessed are primarily exposed to cyclones and storms, bushfires and extreme heat. At the Stuart Highway and Tablelands Highway intersections, disruptions can result in 78 and 82 per cent of freight respectively completely obstructed.

Gregory Development Road: Vulnerability rating: High

Queensland's 549km Gregory Development Road connects LGAs from Charters Towers to Cairns via an inland route providing access to the Atherton Tablelands. Cropping, fuel, horticulture and livestock each represent 15 per cent to the total freight task, while wood products represent 10 per cent. Importantly, the KFR provides access to markets for primary produce, with 40 per cent of all movements originating at a property. The KFR passes through five LGAs and supports supply chain paths for over 143 LGAs. The three intersections assessed are primarily exposed to cyclones and storms and flooding. At the Palmerston Highway and Lynd Junction intersections, disruptions can result in 88 and 97 per cent of freight respectively completely obstructed.

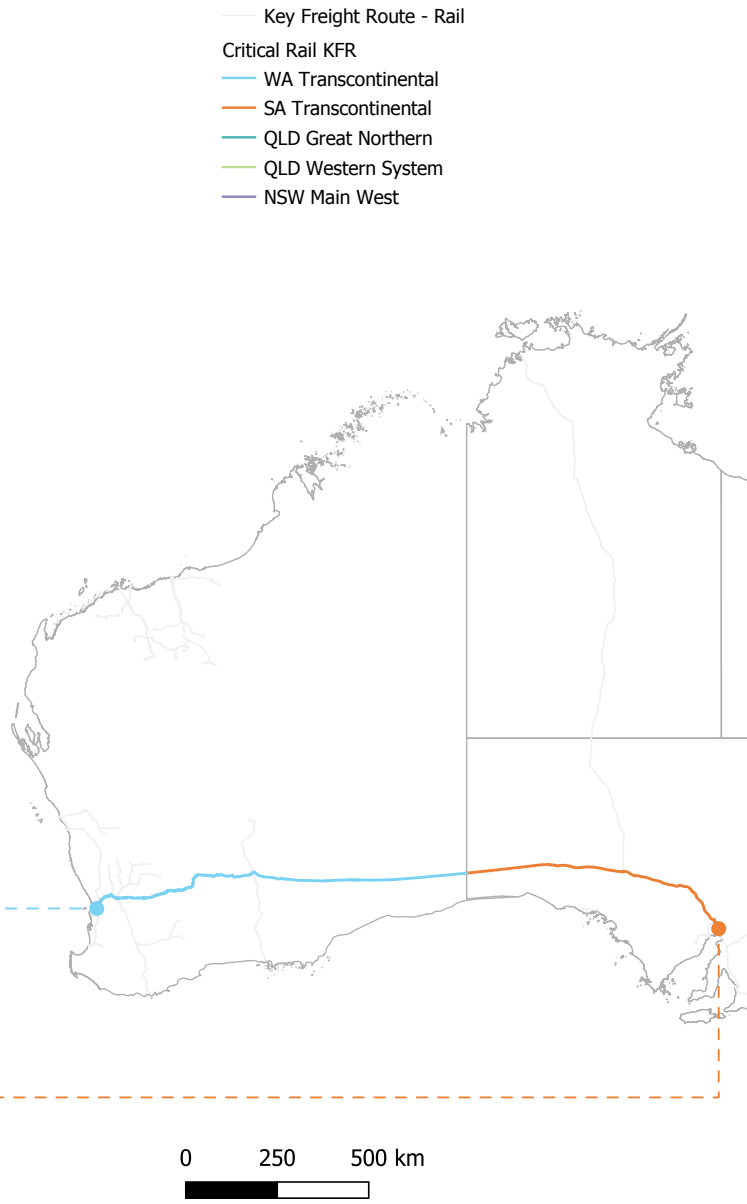
Stuart Highway: Vulnerability rating: High

The 2,781km Stuart Highway is a critical north – south route that runs between Port Augusta in South Australia and Darwin in the Northern Territory via Alice Springs. Fuel transport represents 32 per cent of the total freight task. Mining and livestock each represent 20 per cent of the total freight task. 40 per cent of movements along the KFR originate at a property or port, and 20 per cent are destined to a port. The KFR passes through 16 LGAs and supports supply chain paths for over 283 LGAs. The three intersections assessed are primarily exposed to flooding and extreme heat. At the Victoria Highway intersection, disruptions can result in 100 per cent of freight completely obstructed.

Figure 4. Critical rail KFRs with high and very high vulnerability ratings

Western Australia Transcontinental Line:
Vulnerability rating: Very High

The Western Australian Transcontinental Line carries 12.7 million tonnes of annual freight – largely iron ore, grains and general freight. The average cost per tonne is $47.79. The assessed rail breakage point is situated west of Perth, near Toodyay, and is primarily exposed to flooding and seismicity. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Great Eastern Highway by 271 per cent and an additional total annual cost of $551 million, mainly due to large volumes of mining freight switching to road, which is unlikely to occur in practice due to the large vehicle fleet requirements.

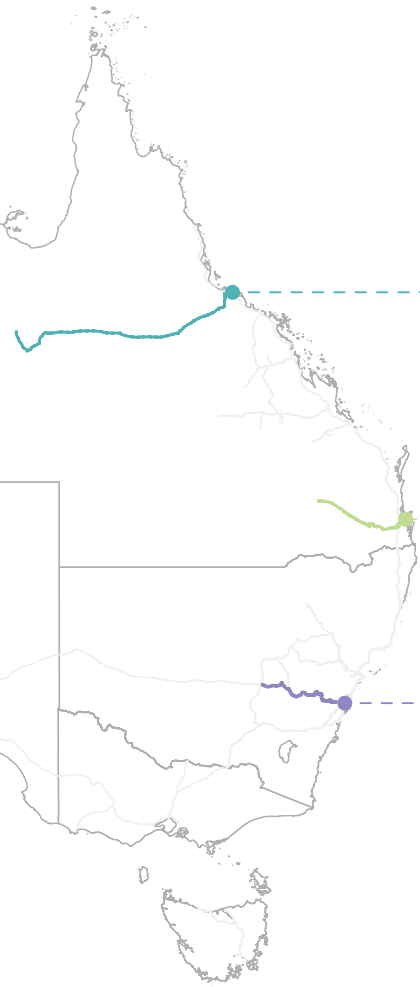


South Australia Transcontinental Line:
Vulnerability rating: High

The South Australia Transcontinental Line carries 2.2 million tonnes of annual freight – largely general freight of which 85,000 tonnes travels to Darwin. The average cost per tonne is $194.21. The assessed rail breakage point is situated northwest of Port Augusta, near Pimba, and is primarily exposed to seismicity and extreme heat. While flooding examples along the KFR were noted, flooding exposure data provided to the Review did not identify this as a primary risk and therefore, was not used to calculate the vulnerability rating. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Eyre Highway by 133 per cent and an additional total annual cost of $445 million.

Queensland Great Northern Line: Vulnerability rating: High

The 950km Queensland Great Northern Line carries 2.3 million tonnes of annual freight – largely minerals, and connects to numerous connectors and terminals. The average cost per tonne is $41.45. The KFR also serves as a cattle service. The assessed rail breakage point is situated west of Townsville on the Mt Isa to Townsville route, and is primarily exposed to cyclones & storms and bushfires. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Flinders Highway by 92 per cent and an additional total annual cost of $45 million.



The Queensland Western System: Vulnerability rating: High

The 300km Queensland Western System Line carries 5.1 million tonnes of annual freight – largely coal, and connects the KFR and other lines servicing southwest Queensland to Brisbane. The average cost per tonne is $20.55. The assessed rail breakage point is situated west of Brisbane in the Lockyer Valley, and is primarily exposed to seismicity and extreme heat. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Warrego Highway by 107 per cent (mostly eastbound) and an additional total annual cost of $39 million.

New South Wales Main West Line: Vulnerability rating: High

The 500km New South Wales Main West Line carries 8.2 million tonnes of annual freight – largely mining and general freight. The average cost per tonne is $40.77. The assessed rail breakage point is situated west of Sydney, near Orange, and is primarily exposed to seismicity and extreme heat. Disruption at the breakage point would see freight take an alternative rail route. While the majority of commodity types would see minimal impact, 96 per cent (6.6 million tonnes) of mining freight (which makes up 81 per cent of total freight volumes) would be completely obstructed.

Resilience initiatives

There are a range of current initiatives across government and industry that aim to lift road and rail supply chain resilience. These include initiatives that monitor the condition and effectiveness of supply chains such as the National Freight Data Hub and CSIRO's Supply Chain Benchmarking Dashboard; raise awareness of future resilience risks in response to climate change and other emerging risks such as the Second National Action Plan for Disaster Risk Reduction; prepare to respond to supply chain disruptions and emergencies such as the work of the National Coordination Mechanism (NCM); and build new infrastructure to improve network resilience such as Inland Rail.

While the number and scope of targeted initiatives to build resilience is significant, the Review has identified a demand for an overarching national approach to address existing gaps and emerging issues in the transport context, to ensure supply chain resilience is considered holistically across the network.

Stakeholders consulted as part of the Review also identified opportunities to further develop and improve data generation, capture and use as an important tool to support decision makers in better understanding Australia's road and rail supply chains and the risks they face. During crises, the current environment of different data standards, systems and sharing permissions of available data make responding to disasters and planning for the future difficult. Improving national governance, collaboration and data (including data collection, standards, sharing, transparency and quality) across government and industry will enable an improved functional and holistic understanding of the freight network and build on the work of the Review to ensure a resilient future.

Key findings

Risks

The Review identified and assessed the impacts of key risks to critical road and rail supply chain routes – including the short and long-term impacts on road and rail infrastructure.

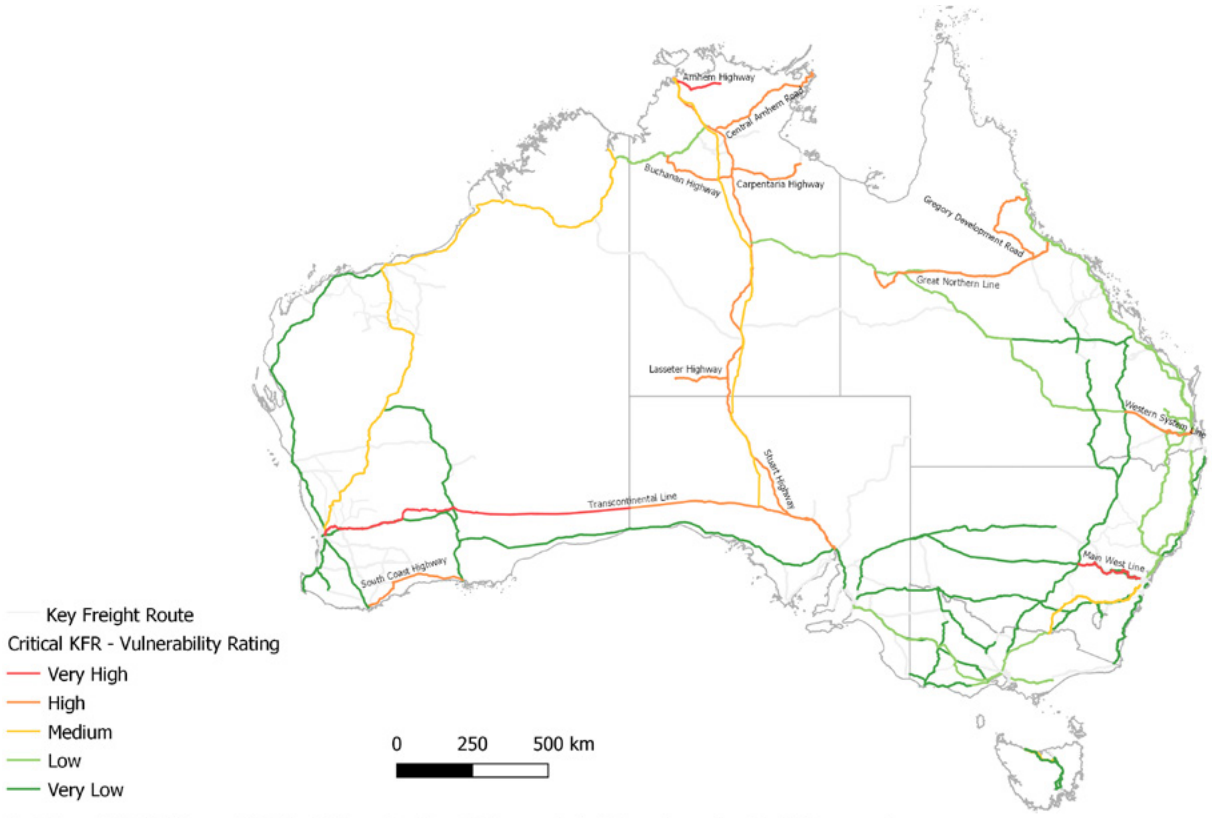
1. There are many natural and human induced risks that can cause disruptions to Australia's road and rail supply chain routes. While the Review found no specific taxonomy of key risks that classify or prioritise risks and threat levels in a freight context, there is existing research that provides an insight into a number of key current and generally accepted risks to road and rail supply chains.
2. Australia's road and rail supply chains are generally resilient. However, recent events such as the COVID-19 pandemic and extreme weather events have highlighted an increasing need to build and strengthen resilience into the future.
3. Flooding was identified as the most significant risk to Australia's road and rail supply chains, reflecting its ability to cover a widespread geographic area and cause disruption (including precautionary closures) across multiple jurisdictions at one time (e.g. recent national flooding events in January and October 2022).
4. While the immediate impacts of identified risks are generally well understood, the Review has also identified the longer term impacts these risks have on road and rail infrastructure. For example, flooding can cause temporary inundation and closures of freight corridors, resulting in delays and disruptions to freight flows. However, prolonged and extreme levels of flooding can lead to increased soil moisture and impact soil and track stability, which could result in lengthy repair and maintenance timeframes.
5. Australia's climate is changing, resulting in increasing frequency and severity of extreme weather events. Predicted increases in heavy rainfall intensity and events will increase the number of disruptions to road and rail supply chains through cyclones, storms and flooding. The increase in frequency and severity of natural disasters will result in greater impacts to road and rail supply chains such as prolonged road closures, rail disruptions and the possibility of some regional communities becoming isolated or cut off for extended periods of time.
6. Establishing a common, long-term understanding of the potential impacts of a changing climate nationally and locally (such as consistent climate risks and resilience scenarios), will be useful to inform future land use and infrastructure planning and decision making.
7. Human induced risks (such as cyber threats and extremist events) are also threats to Australia's road and rail supply chains. Extremist events are difficult to predict, especially when carried out by singular or small groups. While there is no current known threat, road and rail infrastructure such as hubs may be future targets given they are major thoroughfares. In particular, rail networks have unique features that make them inherently vulnerable to attack.
8. There are a variety of other relevant existing and emerging risks, including pandemics; shocks to the global supply chain; space weather events; and issues relating to the increasing freight task, workforce, coordination, capacity and capability. While these risks fall outside the scope of the Review's Terms of Reference, they can have significant impacts on Australia's road and rail supply chains and should be considered and addressed as part of improving future supply chain resilience.
9. There are also other unknown risks that may emerge or occur at any given time (for example, the COVID-19 pandemic and its subsequent impact on cross border supply chain routes). These risks are difficult to plan for and address as it is impossible to know when, where and how they may impact road and rail supply chains.

Critical supply routes

The Review identified critical road and rail supply chain routes (routes that transport large quantities of freight or are critical to supplying essential goods or services across Australia) at highest risk of failure, by determining the vulnerability of these routes (i.e. the likelihood and consequence of a risk occurring and the adaptability of the route in response to disruption).

10. Based on multiple criteria, 65 road and rail supply chain routes were identified as critical. Criteria included assessing the overall volume of freight carried, routes handling multiple commodity types, the proportion of freight that are deemed essential and importance of the route to communities (Figure 5).
11. Of the 52 critical road KFRs assessed, the Arnhem Highway, Gregory Development Road, South Coast Highway, Buchanan Highway, Carpentaria Highway, Central Arnhem Road, Lasseter Highway and Stuart Highway were determined have a high or very high vulnerability rating. Disruption to these routes would impact hundreds of LGAs along their length and beyond, and could result in some communities being completely cut off from essential freight using these routes. The majority of the most vulnerable critical routes are located in the Northern Territory.
12. Of the 13 critical rail KFRs assessed, the East-West rail corridor (running through Western Australia and South Australia), New South Wales Main West Line, Queensland Great Northern Line and Queensland Western System Line were determined have a high or very high vulnerability rating. The breakage points assessed on these routes carry approximately 30 million tonnes of freight annually and in some cases of disruption, would be too much to practically mode shift to road.

Figure 5. Critical KFRs assessed by the Review



Critical KFRs with very high and high vulnerability ratings are labelled in this figure. See Figure 12 for more detailed information on the critical KFRs assessed

Resilience initiatives

The Review completed a stocktake of recent relevant work by government and industry intended to identify and mitigate Australian domestic road and rail supply chain risks.

13. There are a range of existing initiatives by government and industry intended to contribute to the resilience of road and rail supply chains. Initiatives vary from strategic guidance at a broader national level (such as the National Freight and Supply Chain Strategy (NFSCS) and the National Urban Freight Planning Principles), commonly lead by the Australian Government, to more targeted location-specific work, commonly led by states and territories (such as infrastructure investments that build new or upgrade existing parts of the freight network).
14. While there are a broad range of actions and commitments across government and industry currently underway or planned to address natural and human induced risks in general, there are not many initiatives specific to the transport or supply chain context.

Data

The Review uncovered data gaps, consistency and accessibility issues that present a barrier for decision makers to better understand and be assured of the future resilience of Australia's road and rail supply chains. Improving these data provisions can enable a better holistic understanding of the freight network and its characteristics and needs across the country, to ensure the network is able to evolve and adapt to disruptions and remain resilient.

15. Stakeholders highlighted priorities around:
    - Improving the quality and accessibility of supply chain data (including real time freight movements, current disruptions and asset quality); and
    - Further research and analysis into topics such as environmental scenario modelling and forecasting, current infrastructure capacities, and quantifying resilience costs and benefits.
16. There is currently no single standardised format that data is collected and stored, including a lack of a common (or compatible/connected) operating platform to efficiently share this information. The ability to share data efficiently is also limited by commercial in-confidence requirements, competition regulations and laws, and trust between entities to safely share and secure such data.
17. While there is still significant work to be done in the data space to improve road and rail supply chain resilience, there are a number of current data initiatives across government that aim to address some of the identified gaps, including the National Location Registry[1] and National Service Level Standards for Roads. Further improving and promoting efficient and targeted data generation, capture, sharing and use will better enable decision makers in government and industry to effectively and accurately assess, inform and improve road and rail supply chain resilience.

1 The National Location Registry, a key project under the National Freight Data Hub, is a central digital platform containing accurate physical pickup and delivery locations, including associated freight attribute information. The initiative is important in lifting supply chain resilience as it ensures a standardised communication method and format, consistent capturing and disseminating of accurate location data, and an opportunity to digitalise this important aspect of supply chain management.

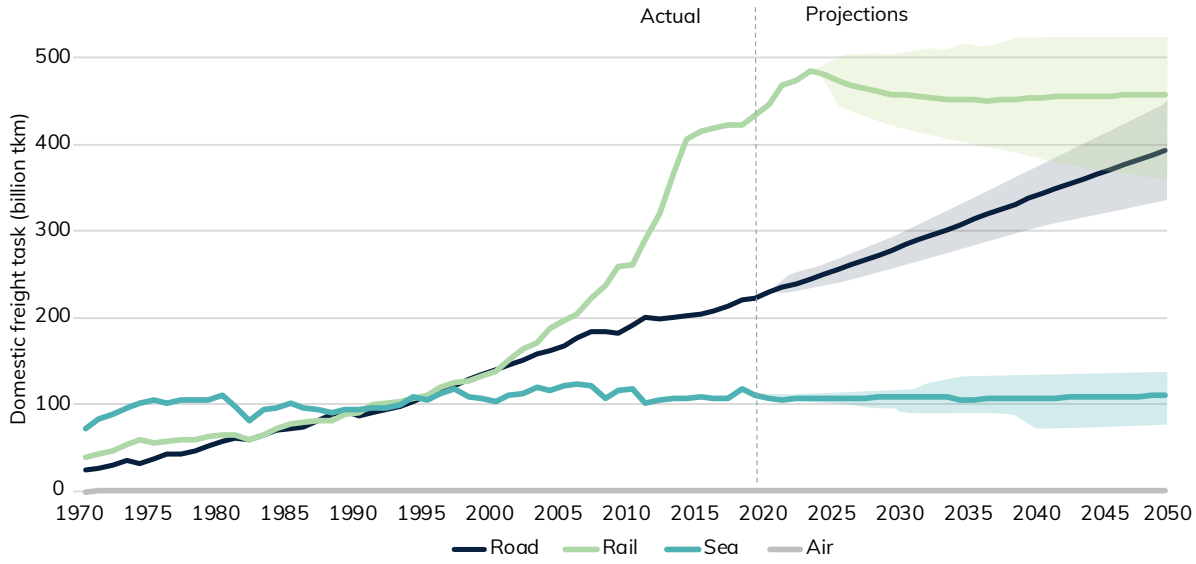
1. Introduction

Australia's domestic freight task has significantly increased over the last 40 years. This is expected to continue to grow by up to 50 per cent between 2020 and 2050 (BITRE 2022) (Figure 6).[2] Road and rail freight now dominate Australia's domestic freight activity, with 235.4 billion tonne-kilometres (tkm) and 453.1 billion tkm of freight moved respectively in 2020–21 (BITRE 2021). The nature of our freight task is also changing, reflecting evolving business practices, new technologies and consumer demand, with urban freight forecast to increase by nearly 60 per cent to 2040 (DITRDCA 2019).

Australians depend on efficient and reliable supply chains to meet this growing and changing demand, but disruptions from recent events including catastrophic bushfires, flooding and the COVID-19 pandemic have raised concerns about the resilience of the nation's supply chains in the face of disasters (Productivity Commission 2021).

In March 2022, BITRE was commissioned to undertake Phase 1 of a review into Australia's road and rail supply chain resilience. The Review Terms of Reference are found in Appendix A.

Figure 6. Australia's domestic freight task, by mode of transport



Note. Due to comparatively smaller numbers, air freight may be difficult to distinguish from the x-axis in the chart above.
Source: Australian Aggregate Freight Forecasts - 2022 (BITRE 2022)

This report looks to provide an evidence base to support building resilience of our road and rail supply chains, and is structured as follows:

- Chapter 2 defines and determines critical road and rail supply chain routes in Australia.
- Chapter 3 examines the risks to road and rail supply chains.
- Chapter 4 analyses best practice risk frameworks, determines a risk framework for the Review and assesses the resilience of critical supply chain routes using the framework.
- Chapter 5 presents a stocktake of recent relevant initiatives to address supply chain resilience.
- Chapter 6 provides governance and data considerations and requirements for dealing with road and rail supply chain resilience.
- Chapter 7 suggests areas of focus for consideration under Phase 2 of the Review.

2 In a high growth scenario. In a median growth scenario, total freight is forecasted to grow by 25 per cent.

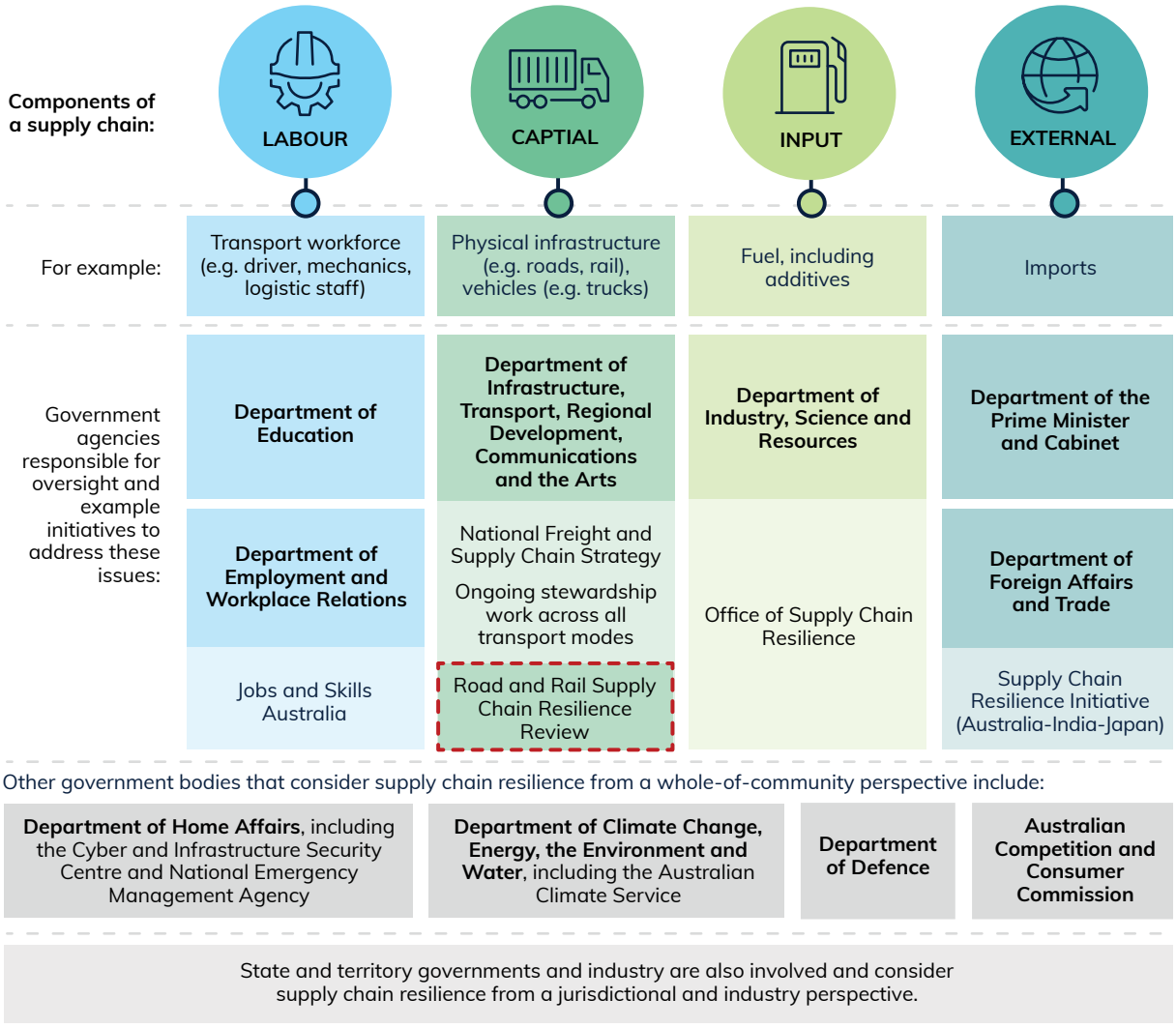
1.1 Policy context and scope

A supply chain can be broken down into a number of components: labour, capital, input and externalities. The Review focuses on the capital component of the supply chain – Australia's road and rail and other linked infrastructure (Figure 7). Topics such as international supply chain vulnerability, the transport workforce, other transport modes and critical inputs to the transport sector are outside the scope of the Review and are addressed by other areas and work across government, including the Australian Government's Office of Supply Chain Resilience (OSCR), the NFSCS and Jobs and Skills Australia.

There is a range of existing initiatives by government and industry that contribute to better understanding and managing road and rail supply chain risks to build resilience. The Review considers supporting work, including but not limited to the:

- Australian Infrastructure and National Rail Action Plans;
- NFSCS (including the National Freight Data Hub);
- National Urban Freight Planning Principles;
- Royal Commission into National Natural Disaster Arrangements;
- Productivity Commission Study into Vulnerable Supply Chains; and
- National Key Freight Routes.

Figure 7. Where the Road and Rail Supply Chain Resilience Review sits in the context of the resilience landscape



1.2 Our approach

The Review is broken down into two phases:

- **Evidence base** (this report) consisting of consultation findings, problem definition, identification of risks, critical road and rail supply chain routes and data gaps, and designing a framework for response; and
- **Response phase** consisting of consultation of findings from the evidence base to develop and present pragmatic options for government to mitigate or address risks to critical road and rail supply chains.

The Review will conclude and report to government by December 2022.

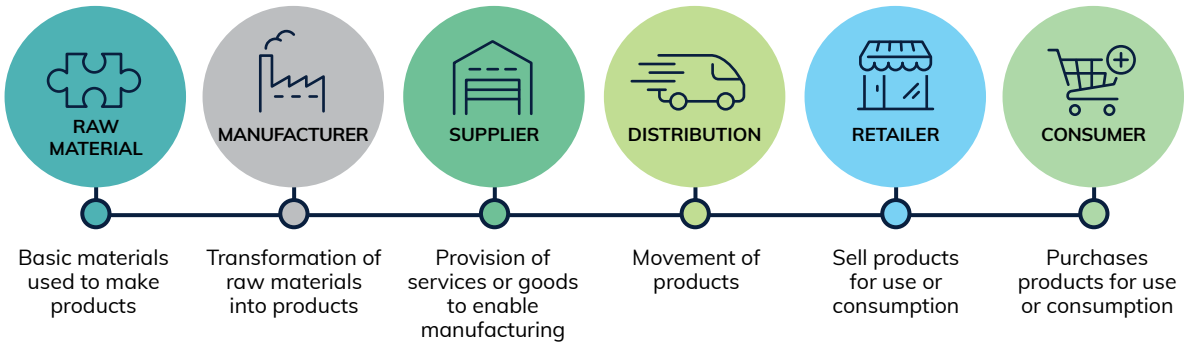
In building the evidence base to inform road and rail supply chain resilience, this report draws on:

- **CSIRO's Transport Network Strategic Investment Tool** (TraNSIT) to undertake scenario modelling to identify and assess disruptions to critical supply chain routes across Australia's road and rail network. The full CSIRO report is found at Appendix B.
- **Deloitte** conducted a stocktake of risks that impact road and rail supply chains, initiatives that address these risks, and spatial vulnerability analysis of key freight routes. The full Deloitte report is found at Appendix C.
- **Findings from stakeholder engagement**. The Review consulted widely with government and industry to ensure the Review considered and captured the key issues around road and rail supply chain resilience. The Review also engaged closely with the Freight Industry Reference Panel (FIRP), and internal expertise. A list of stakeholders consulted with is found at Appendix D.

1.3 Defining supply chains

Australian freight supply chains are typically vast, reflecting the size of the country, and comes in many different forms. In its most basic form, a supply chain is the network of people, companies, products and services that gathers raw materials, transforms them into products and transports them to their final destination (Figure 8) (DITRDCA 2019).

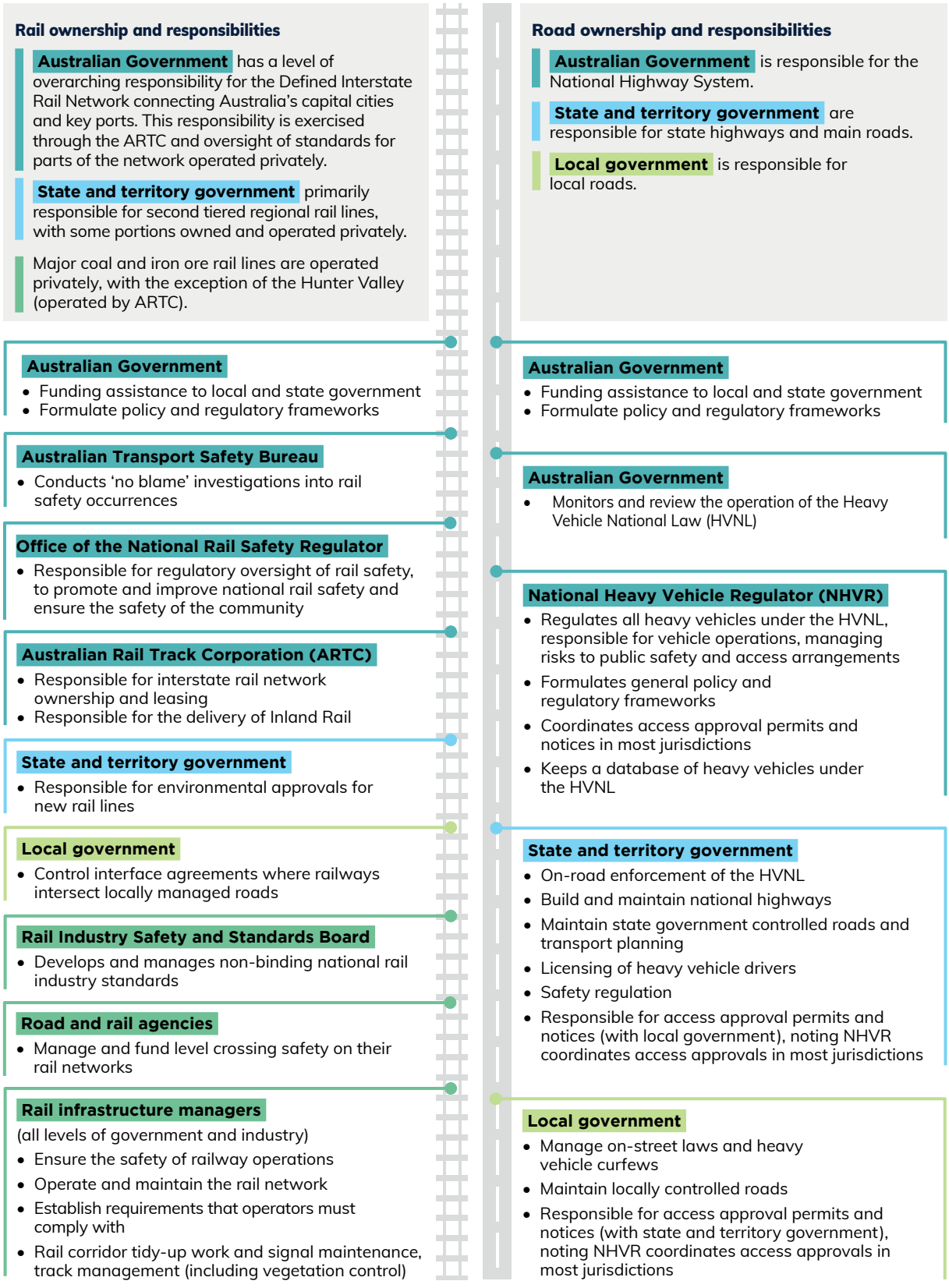
Figure 8. Supply chain definition



The role of resilient road and rail infrastructure is critical to ensure supply chains remain intact, are efficient and continue to supply Australian with essential goods and services.

All levels of government and industry have a role to play in helping Australia meet its freight needs, including managing and maintaining assets and networks, developing and providing regulatory settings and standards, and ensuring the safety of operations, now and in the future. Figure 9 provides an example of how government and industry collaborate in the operation of road and rail supply chains.

Figure 9. Illustration of how government and industry collaborate in the operation of road and rail supply chains



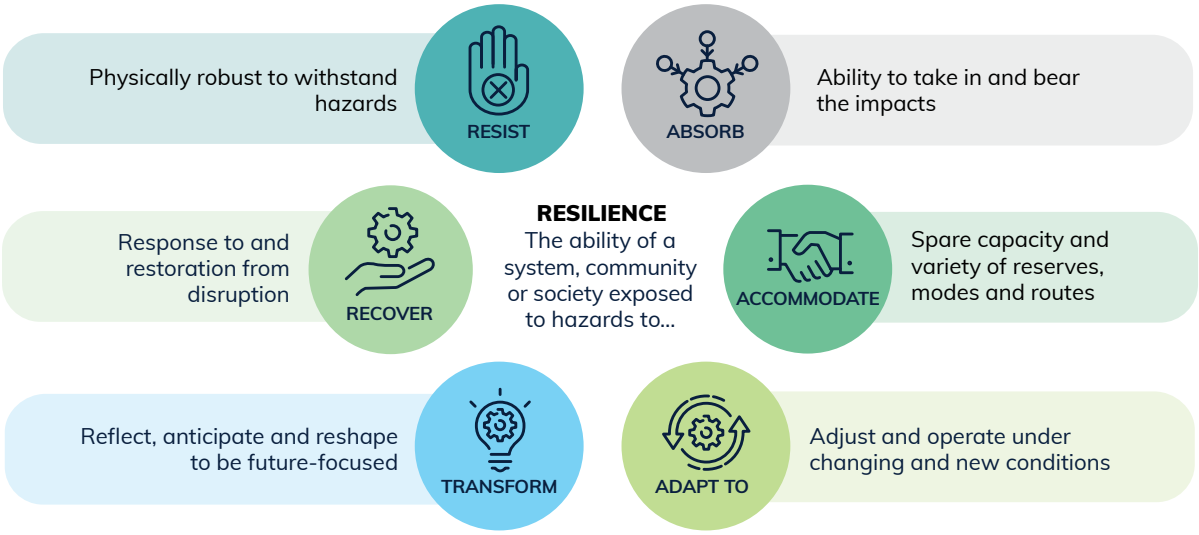
Source: About Us (Australian Rail Track Company, 2022); Laws and Regulations (National Transport Commission, n.d.); National Freight and Supply Chain Strategy (DITRDCA 2019); ONRSR (Office of the National Rail Safety Regulator n.d.); Overview of the ATSB (Australian Transport Safety Bureau 2022); What is Inland Rail (ARTC n.d.)

1.4 Defining supply chain resilience

The Review found various definitions of resilience used across government and industry, depending on the lens though which resilience is considered, highlighting the multifaceted nature of the concept. The Review adopts a broader definition of resilience from the Australian Institute for Disaster Resilience (Figure 10):

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Figure 10. Resilience definition

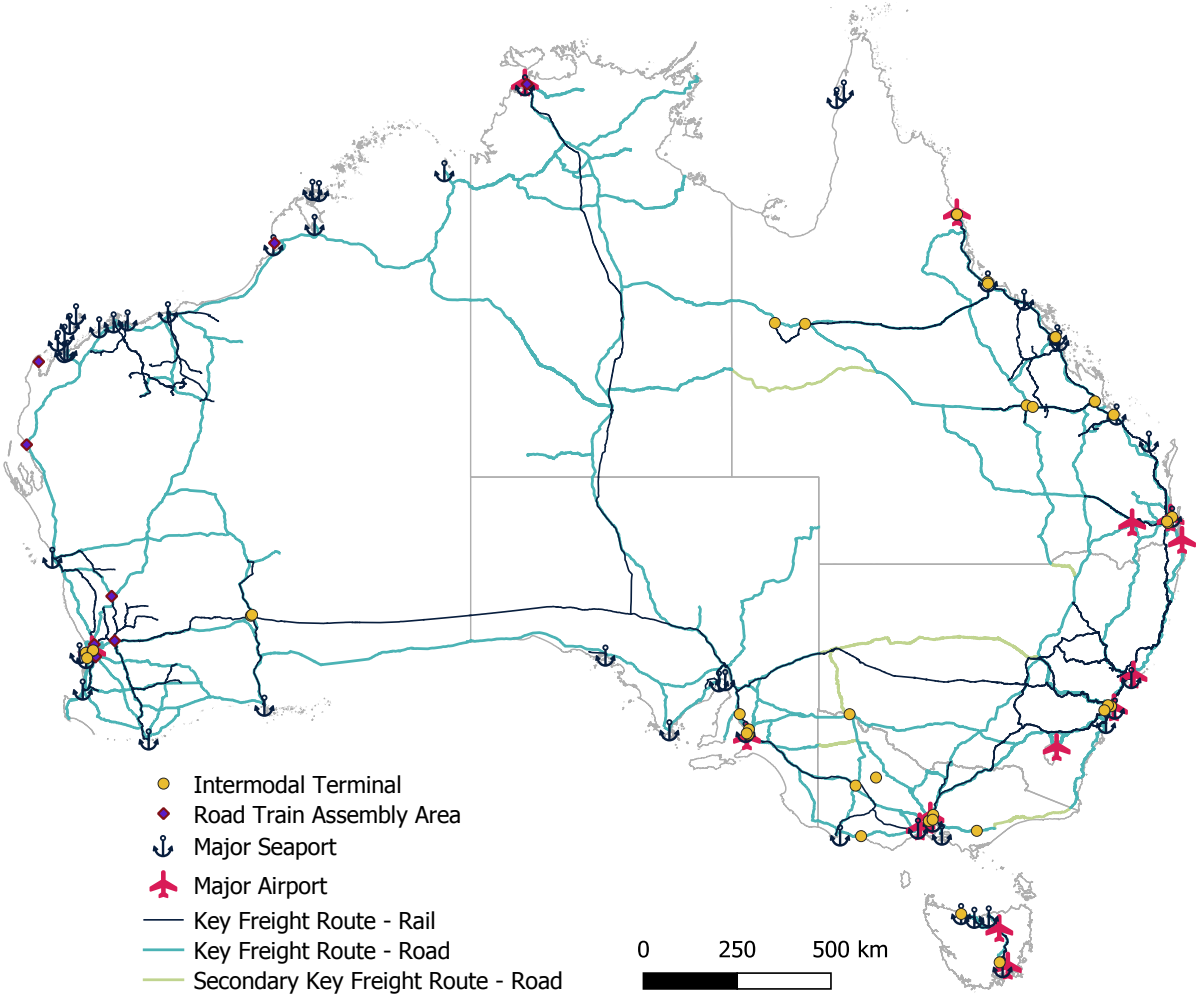


2. Critical supply chain routes

2.1 Key freight routes

The National Key Freight Routes (KFRs) are routes identified through collaboration by Commonwealth, state and territory governments and industry, to develop a more comprehensive understanding of Australia's freight system. The KFR map (Figure 11) provides a detailed picture of the road and rail routes connecting Australia's nationally significant places for freight, including ports, airports and intermodal terminals. The map is a policy tool that can inform strategic planning, operational and investment decisions across the Australian freight network.

Figure 11. Key Freight Routes map



Source: National Key Freight Routes Map (DITRDCA 2020)

The Review utilised CSIRO's TraNSIT to identify and assess the resilience of a subset of 65 critical road and rail supply chain routes from the national KFRs across Australia (Figure 12). This is equivalent to a coverage of over 60 and 50 per cent of total road and rail KFR lengths respectively.[3] KFRs were chosen based on the following criteria:

3 See Chapter 6.2 for more information.

Road:

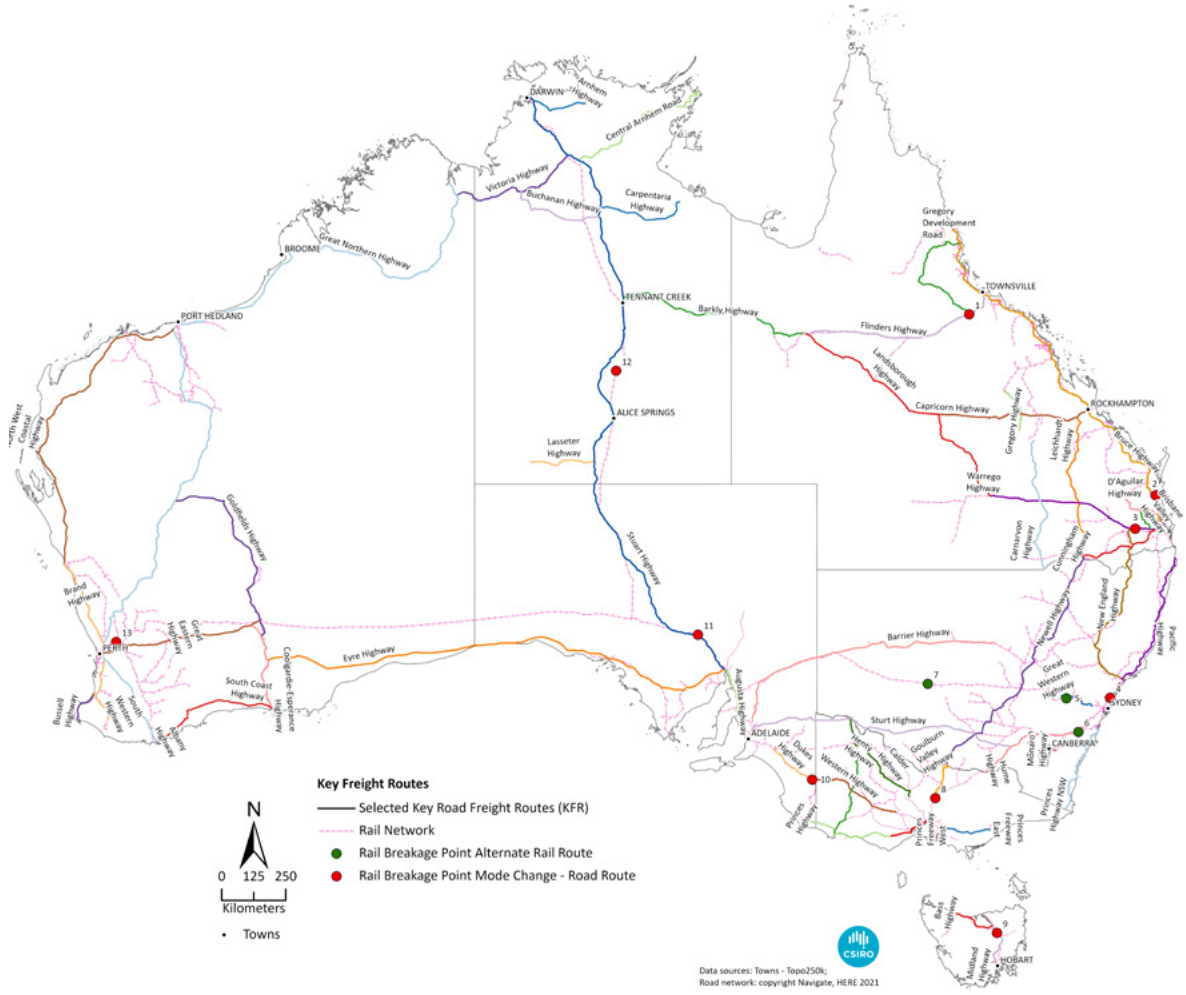
- 44 KFRs were selected due to high overall volume use, value and proportion of essential commodities. To ensure that each jurisdiction is represented, a minimum of the top two KFRs based on the high-use criteria were included for each state or territory.
- 8 KFRs were selected where Local Government Areas (LGAs) are dependent on that accessible freight route for supplies or a pathway to markets.

Rail:

- 13 KFRs were selected based on the diversity of their commodities carried and freight volumes, with a preference for routes connecting major centres.

From here onwards, selected KFRs selected for analysis are referred to as 'critical KFRs' in the Review. Refer to Appendix B for a detailed assessment for how each of the critical KFRs were selected.

Figure 12. Selected critical KFRs for TraNSIT analysis



The TraNSIT analysis captures the impacts of disruptions to road and rail supply chains. Each critical KFR was subject to a disruption, defined as a set of closures at high use intersections along the route, with the TraNSIT model then producing multiple metrics to assess the relative resilience of each critical KFR. Metrics constructed include:

- Relative detour cost (the cost of having to take an alternative route when a blockage occurs);
- Relative value of freight unable to reach destination;
- Relative impact on the population; and
- Relative risk of interrupted movements.

2.2 Essential commodities

Identifying critical supply chain routes requires an understanding of and establishing what commodities are considered essential to Australian communities and businesses. However, identifying a definitive list of essential commodities is a complex and subjective undertaking. The Review found there is no single Commonwealth approach to defining what commodities are 'essential' at a national scale. A number of studies analysing supply chain resilience have developed frameworks to identify critical commodities in times of crisis, including the NDRRF and Productivity Commission's Study into Vulnerable Supply Chains (Table 1). While these frameworks are adapted across various levels of government as a tool to identify essential commodities in response to disaster events, they do not provide a definitive list to be considered in anticipation of an event from a supply chains system perspective.

Table 1. Comparison of essential commodities listed by various Commonwealth frameworks

Essential good/ service	National Disaster Risk Reduction Framework	Productivity Commission's Study into Vulnerable Supply Chains	Royal Commission into National Natural Disaster Arrangements	Critical Infrastructure Centre	Department of Home Affairs (DHA) COVID-19 Sectors	National Reconstruction Fund and Priorities	DHA Essential Goods and Planning Prioritisation – Interim Guidance
Food and beverage (incl. groceries, essential hygiene and packaging)	●			●	●		●
Health and medical		●	●	●	●	●	●
Water	●	●	●	●			●
Energy (incl. clean energy, recycling, electricity)	●	●	●	●		●	
Communications	●	●	●	●			
Transport	●	●		●		●	
Finance and tax	●	●		●			
Agriculture, forestry, fisheries, livestock and foodstock					●	●	●
Critical infrastructure					●		●
Supply chain logistics and facilitating freight services (incl. fuel)					●		●
Commonwealth government				●	●		
Defence		●				●	
Engineering, minerals processing and mining					●		
Aged care					●		
Fire retardant							
Maritime					●		
Primary industry					●		
Resources						●	
Enabling capabilities						●	
Goods for vulnerable cohorts							●

The Review has taken a broad approach in considering a list of essential commodities, in which TraNSIT has used to identify, assess and select the critical KFRs for further analysis. The Review's definition of essential commodities includes those that have the following characteristics:

- Principally for household consumption or immediately enters as an input for household consumption (e.g. food (unprocessed and processed) and water (components for the operations and maintenance continuity of water supply and sewage services));
- Fuel that is essential to maintain supply chains; and
- Construction and transport material necessary to respond to broken supply chains.

The Review acknowledges that while this list covers necessities that Australians cannot live without for a few days and the necessary commodities to facilitate the transportation and distribution of those goods, inputs into supply chains in areas such as defence are also important to consider in preparing for and responding to disaster events.

Case study: Essential good and planning prioritisation – interim guidance

In early February 2022, severe flooding resulted in major disruptions on the East-West rail corridor, with damage to over 300km of track servicing Western Australia, South Australia and the Northern Territory. This rail line is the major pipeline for the movement of goods into and out of Western Australia, with approximately 80 per cent of land-based freight moving via this route. Due to capacity and workforce issues (exacerbated by COVID-19), a significant backlog in freight was experienced, with the rail line unable to restart at full capacity for 24 days.

In response, the Department of Home Affairs developed the 'Essential Goods and Planning Prioritisation – Interim Guidance' guidelines to support the prioritisation and movement of essential goods during this time (ACCC 2022b). The framework was non-prescriptive, and aimed at supporting key stakeholders, particularly Western Australian, South Australian and Northern Territory governments and industry, in their decision-making processes to manage the freight backlog. The guidelines identified the following priority essential items:

a. Essential food, beverages, and groceries (including essential hygiene products and essential packaging);

b. Water and waste-water treatment supplies;

c. Urgent medical supplies (including COVID-19 related supplies);

d. Goods for vulnerable cohorts;

e. Goods that are critical to enabling, supporting or facilitating freight services that carry essential goods (including diesel exhaust fluid);

f. Essential supplies necessary to the operation of critical infrastructure; and

g. Essential food stocks for animal and aquaculture welfare.

The guidelines were utilised by industry when applying for an urgent interim authorisation application to the ACCC. The ACCC granted industry's request, permitting the cooperation and sharing of information by supply chain companies to ensure critical retail goods, including food supplies, were able to reach consumers and businesses (ACCC 2022a).

2.3 Modelling outputs

2.3.1 TraNSIT analysis

TraNSIT maps millions of vehicle trips across thousands of supply chains routes in Australia, and has been used by the Review to assess the impacts of road and rail supply chain disruptions. While TraNSIT has been identified as the ideal model to understand road and rail supply chain resilience, the Review acknowledges limitations to the data that TraNSIT has access to, such as the current conditions of road and rail assets and the availability of commodity data. The Review also recognises there are alternative transport modes (such as aviation and maritime) and routes that, while out of the Review's scope, are integral to ensuring the resilience of Australia's domestic supply chains now and into the future. Refer to Appendix B for further details of TraNSIT and its methodology.

For the critical KFRs selected, TraNSIT provides data and insights into:

- The impacts of disruptions to essential commodities of each critical KFR; and
- The impacts of disruptions to all commodities of each critical KFR.

Noting the subjectivity around defining essential commodities, the Review has focused on the impacts of disruptions to critical KFRs for all commodities. This is also applicable to the methodology adopted when applying the Review risk assessment in Chapter 4.

2.3.2 Road

As described in Chapter 2.1, up to three strategically important intersections were closed along each critical KFR to simulate the potential impacts of a natural or human induced disaster. The impacts resulting from these closures were then modelled to determine, among other metrics:

- The volume of freight obstructed or detoured (including the associated costs of that detour); and
- The impact on communities (by understanding commodities which were not able to reach their destination LGA, or be exported from the LGA to the market).

The following section outlines the trends identified for each state and territory. A detailed breakdown of each road route can be found in the full TraNSIT report (Appendix B) or in the Review's summarised analysis (Appendix F).

State and territory analysis[4]

New South Wales

Generally, New South Wales's critical KFRs were resilient to disruption. The closure of most intersections on these routes resulted in low to very low impact on freight flows. Most to all freight was able to be rerouted, and it could be done at a relatively low increase to freight costs, with detour costs between $2-15/tonne. For those few supply chains obstructed, the impact on the communities was mainly low to moderate with and exception to the New England Highway – Gwydir Highway intersection, which resulted in a medium to high impact.

Victoria

Generally, Victoria's critical KFRs were resilient to disruption. The closure of most intersections on these routes resulted in low to very low impacts on freight flows. Most to all freight was able to be rerouted, and it could be done at a relatively low increase to freight costs, with detour costs between $2-12/tonne. Community impacts were mostly very low to low. The most impacted KFR seen in the modelling was the Western Highway at the intersections of the Borung and Henty Highways, which showed medium to high values for the impact to community metrics, due to some obstructed freight.

4 In the TraNSIT analysis, KFRs that cross state or territory borders were either modelled as separate KFRs (if they changed name) or assigned to the state or territory in which the largest portion of the KFR was located. The exceptions were allocating the Barton Highway to the Australian Capital Territory, the Stuart Highway to South Australia, the Barkly Highway to Queensland, and the Victoria Highway to Western Australia. The Review allocates the three latter routes to the Northern Territory.

Queensland

Generally, Queensland's critical KFRs were resilient to disruption, with the closure of most intersections on these routes resulting in low to very low impacts freight flows. The exception to this was the Gregory Development Road KFR, which saw moderate to high impacts on freight movements and very high impacts on communities. Modelled disruptions resulted in up to 100 per cent of freight being obstructed, with disruptions at the Palmerston Highway and The Lynd Junction intersection resulting in high community impacts. For rerouted freight, detour costs were generally low across all critical KFR intersections studied.

South Australia

Each critical KFR analysed in South Australia showed very different resilience outcomes. The Augusta Highway was the least impacted from disruption, with an exception at the Range View Road intersection, where there was high community impact (with 86 per cent of construction materials obstructed for some LGAs). While the Eyre Highway showed very low to low impacts due to disruption across its modelled intersections, the cost of detouring freight was high at some locations, with the detour costs through the closure of Flinders Highway intersection reaching up to $238/tonne.

Western Australia

Critical KFRs analysed in Western Australia showed various resilience outcomes. The Bussell, Great Eastern and South Western Highways were least impacted by the modelled intersection closures, with low to very low impacts on freight and communities. Modelled disruptions resulted in detour costs between $1-5/tonne. The Brand, South Coast, Great Northern and Goldfields Highways were the most impacted critical KFRs, showing medium to high community impacts due to obstructed freight. Modelled disruptions resulted in detour costs between $10-600/tonne on these routes.

Tasmania

Generally, Tasmania's critical KFRs were resilient to disruption. The closure of most intersections resulted in very low to low impacts on freight flows with the exception of the Bass Highway at the Tarleton Highway intersection. Modelled disruptions at this intersection showed 100 per cent of freight obstructed on this route, resulting in a very high community impact, with 156 LGAs impacted by the obstruction. Tasmania is an island economy and over 99 per cent of freight by volume, leaving and entering the state, is transported by sea (Department of State Growth 2016). The Review acknowledges what while maritime is not part of the scope, it is important to understand the role of ports and other connecting points on supply chains, including the Bass Strait, particularly when those routes are disrupted.

Northern Territory

While each critical Northern Territory KFR analysed showed different resilience outcomes, the modelling of disruptions resulted in mostly high to very high impacts on freight flows and communities. Modelled disruptions on a number of intersections resulted in 100 per cent of freight being obstructed, resulting in high to very high community impacts. Where detouring freight is possible, costs are extremely high – over $500/tonne in one instance. These results highlight the vulnerability of the territory's road network to disruptions, and presents a key risk to the resilience of supply chains.

Australian Capital Territory

Generally, the Australian Capital Territories critical KFRs were resilient to disruption. The closure of most intersections for resulted in low to very low impacts on freight flows. Most to all freight was able to be rerouted, and it could be done at a relatively low increase in freight costs, with detour costs between $4-12/tonne. Similarly, community impacts were very low to low as well.

Cluster analysis

As a part of their TraNSIT analysis, CSIRO grouped the modelled intersections of critical KFRs into four clusters, based on similar levels of impact to provide an overview of which intersections and critical KFRs are generally at a higher risk of impacting freight movement or communities when disrupted. The analysis found the majority of intersections belonged in clusters 1 or 2, where the closure of the intersections would have little impact to freight flows or communities. However, there were a number of intersections grouped in clusters 3 or 4 that, should they to close, could cause significant delays, costs and high impacts on communities. Table 2 provides the definition of each cluster and an example critical KFR and intersection. Refer to Appendix B for the full list of intersections grouped in each cluster.

Table 2. TraNSIT cluster analysis

Cluster	Cluster description	State	Critical KFR example	Intersection example
1	The closure of the successive intersections had little impact to the freight or communities.	New South Wales	Hume Highway	Federal Highway
2	Little impact on freight or communities, however the cost incurred was higher for the detoured freight.	Queensland	Barkly Highway	Stuart Highway
3	Very low to low risk of obstructed commodities, however when a freight route was obstructed, the impact on communities was moderate to high.	South Australia	Augusta Highway	Range View Road
4	High impact on freight with large proportion of freight obstructed. Some communities relying heavily on the intersection, meaning that the obstructed freight had a greater community impact, resulting in high vulnerability if the critical KFR was disrupted.	Northern Territory	Buchanan Highway	Victoria Highway

2.3.3 Rail

The methodology used to analyse the 13 critical rail KFRs is different to that of the critical road KFR analysis. Rather than modelling the closure of up to three intersections and progressively disrupting alternative routes, rail breakages were simulated at or near major cities/towns or at a location with high potential flood blockage. Rail freight was then diverted in one of two ways. First, if there was an alternative rail route, then that route was taken. However, if there was no alternative rail route, the freight was shifted onto road and the associated costs were calculated.

For seasonal commodities such as grain and sugarcane, potential disruptions are primarily dependent on the timing and location(s) of breakages in the network.

- Australia's regional rail networks across New South Wales, South Australia, Victoria and Western Australia predominately carry around 24.4 million tonnes of grain per year to major ports or milling facilities, with the subsequent outputs from these facilities travelling via road to consumers. Should a rail breakage occur as a result of natural or human induced disasters after a grain harvest, the associated costs would be much higher than in the off season.
- Sugarcane depends on far north Queensland's rail to transport 30 million tonnes of sugarcane to the mills each year. These railways are generally built for extreme weather. Given the close proximity of the rail line to sugarcane farms (approximately 20kms), an event that disrupts the rail network will likely impact the crops themselves before they are transported, with a cascading effect on the supply chain network.
- Rail routes for coal and iron ore usually carry more than 50 million tonnes of the commodity per year. A disruption to these rail links provides limited to no options for alternative rail paths. Where alternative rail paths are available (e.g. coal freight in the Bowen basin travelling via Emerald), the large detour would not be able to accommodate the frequent number of large coal and iron ore trains. A switch to road transport would be difficult as it would require a large number of suitable vehicles for coal and iron ore, which would not be available. For both the Hunter and Bowen Basin regions, switching coal from rail to road (hypothetically if the road fleet was available), would lead to a significant increase in heavy freight along regional freight routes, including the New England, Dawson and Peak Downs Highways, and Bowen Development Road, among others; and result in significant congestion at intersections within the townships and ports.

A detailed breakdown of each rail route can be found in the full TraNSIT report (Appendix B) or in the Review's summarised analysis (Appendix F).

3. Risk

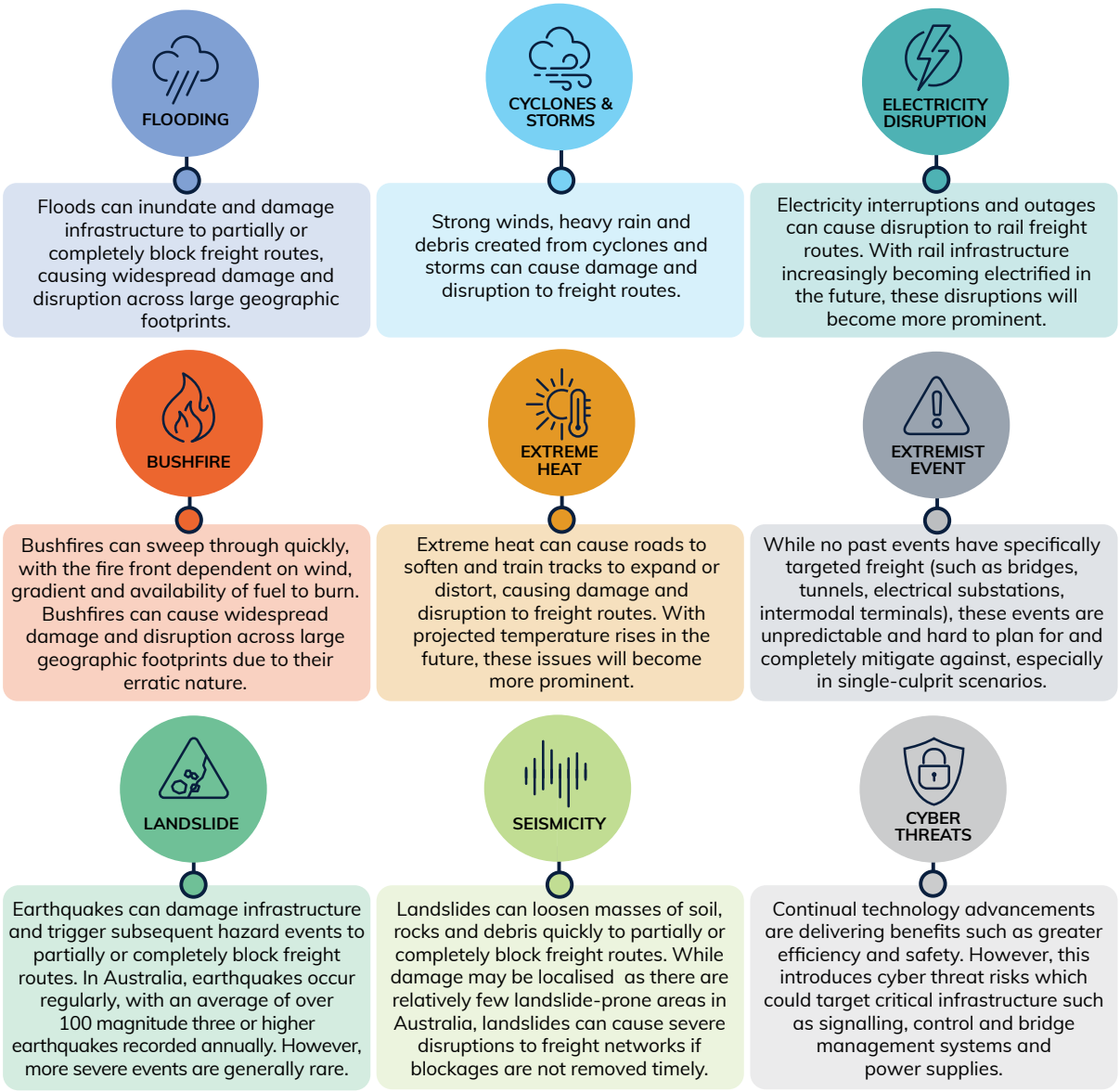
3.1 Taxonomy of key risks

There are many natural and human-induced risks to Australia's road and rail supply chains that can cause disruptions to freight routes. While the Review found no specific taxonomy of key risks in a freight context that classifies or prioritises risks and threat levels, there is existing research that provides an insight into a number of key current and generally accepted risks to road and rail supply chains.

There are 29 hazards identified across state and territory emergency risk assessments that could impact road and rail supply chains – nine of which were identified as key hazards (Figure 13) based on:

- The potential impact of the hazard on road and rail infrastructure;
- How often the hazard appears in state and territory assessments; and
- Whether the hazard is regionally-specific with potentially catastrophic localised consequences.

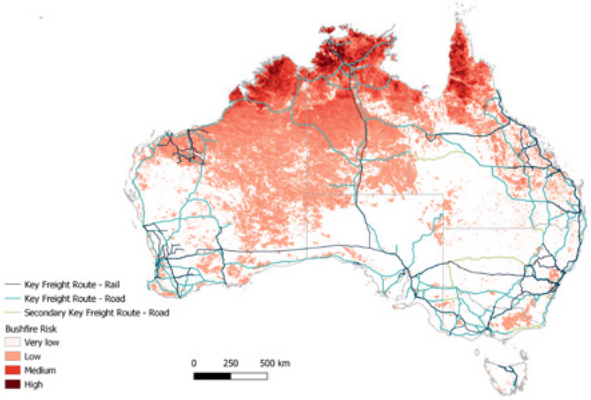
Figure 13. Nine key hazards selected by the Review



Hazards such as bushfires and flooding pose significant risks to Australia's road and rail supply chains, reflecting their ability to cover a widespread geographic area and cause disruption across multiple jurisdictions at one time, including consequences from precautionary closures. The costs associated with bushfires and flooding have been highlighted through recent events such as the Black Summer Bushfires, which caused up to $5 billion worth of damage to the agriculture sector - a sector which depends heavily on road and rail supply chains (Bishop et al. 2021). The Australian Rail Track Company (ARTC) noted recent flooding has caused major damage and disruption on its network across the country. New South Wales has seen extensive flooding since the start of 2022, with parts of the state having received over 700mm of rain, resulting in over 160 broken sections of the rail network requiring repair. The flooding also caused derailment and infrastructure slippage, demonstrating the variety of impacts flooding can have on road and rail infrastructure.

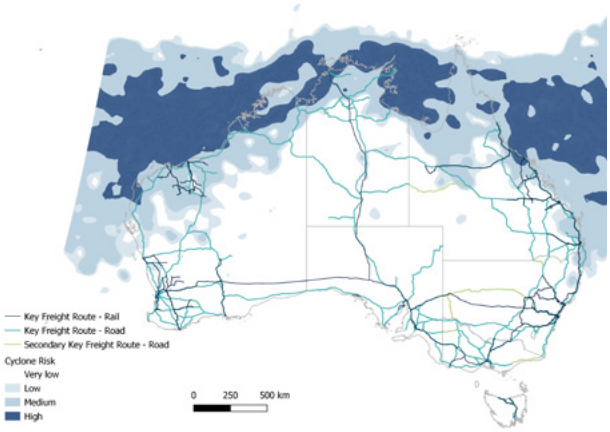
While the identified hazards immediate impacts are generally well understood, the Review has also identified the long-term impacts these hazards have on road and rail infrastructure (Table 3). Figure 14 provides a visual representation of the spread of key hazards geographically across Australia. Bushfires, cyclones, landslides and earthquakes are included as there is publicly available, accessible and consistent national data. While flood data is available, inconsistency in the way data is collected, processed and interpreted across jurisdictions makes it difficult to consolidate and graphically present it accurately at a national scale. See Appendix C for a list of flood data by jurisdiction.

Figure 14. Geographic footprint of risks across Australia



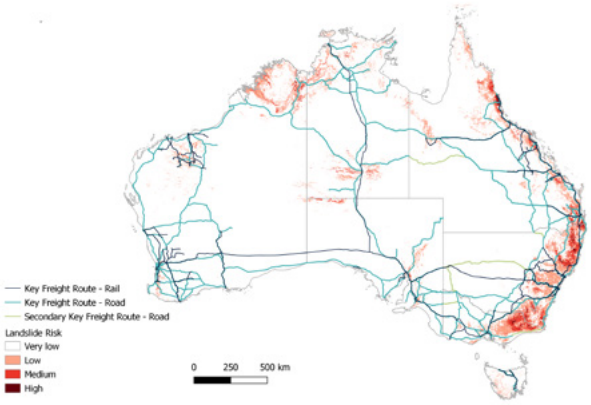
Bushfire risk

Source: 2016 SoE Land National Fire return frequency for Australia (1988 – 2015) (Department of Environment and Energy 2017)



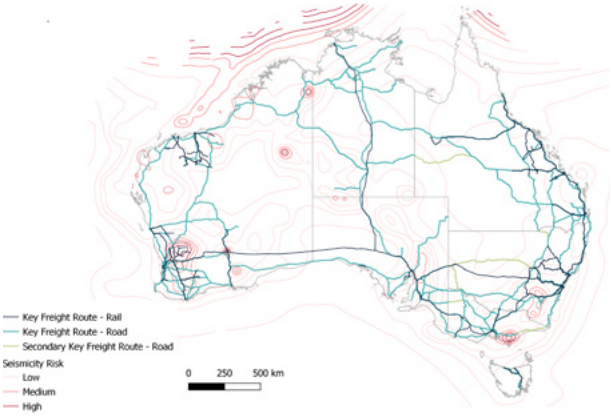
Cyclone risk

Source: Australian Region Cyclone Intensity and Frequency Index – CAMRIS (CSIRO 2015)



Landslide risk

Source: Global Landslide Hazard Map (Global Facility for Disaster Reduction and Recovery 2020)



Seismicity risk

Source: 10% in 50 Year Seismic Hazard Map (Geoscience Australia 2018)

Table 3. Short and long-term impacts of selected hazards on road and rail supply chain routes

Hazard	Short-term impact	Long-term impact
	Freight routes may close due to direct (within the path of the fire) or indirect impacts (precautionary closures). Smoke impacts visibility, leading to heightened safety precautions (e.g. restricted speeds). Route closures result in redirection, causing issues around timing and supply.	Prolonged exposure can lead to physical impacts (e.g. melting, cracking, deformation of asphalt; damage to signaling equipment and other rail infrastructure) that require specialised repair to restore accessibility.
	Flooding can cause temporary inundation and closures (including precautionary closures) of freight corridors, resulting in delays and disruptions to freight flows.	Prolonged and extreme levels of flooding can lead to increased soil moisture and impact soil and track stability, which could result in lengthy repair and maintenance timeframes.
	Landslides can cause supply chain issues and disrupt community access due to closures to road and rail routes.	A landslide can severely damage a road or rail corridor to the extent that it must be closed for a prolonged period of time for cleaning and repairs.
	While existing infrastructure can withstand smaller seismic activity, a severe earthquake could damage track components, signaling equipment or crack road surfaces, causing immediate disruptions.	Earthquakes and other seismic activities can cause significant structural damage such as tunnel collapses and extensive road damage, leading to prolonged route closures.
	Heavy rainfall, lightning and extreme winds present a major risk that may result in the need to reroute freight movement. Cyclones and storms can also cause trees or debris to fall directly onto routes, causing immediate route closures and delays.	Longer term impacts include damage to retaining walls due to extreme wind and heavy rainfall. Prolonged waterbody surges leading to saturation of infrastructure can also cause structural damage.
	Rail impacts including overheating trains and tracks, can cause significant delays, particularly if speed restrictions are applied to prevent spot fires or preventative closures. While historically less impactful on road freight, severe heat can cause bitumen to stick to tyres and damage vehicles and the road.	Constant extreme heat can cause the malfunctioning of rail technology systems and electrical substations. This creates potential disruptions and issues around safety. With the continual electrification of the rail network, extreme heat conditions could see a greater impact on rail in the future.
	The transition towards greater electrification may result in a more volatile power grid due to increase demand on the network, which increases the likelihood of intermittent breaks in power supply to an electrified rail network. Any break in power could cause delays and disruptions to freight flows reliant on electric systems such as signalling.	Severe natural weather events can disrupt power supplies for an extended period of time, cause damage to and prevent infrastructure from operating. These events will likely become more prevalent, increasing the risk of damages associated with electricity disruptions.
	Cyber-attacks (including phishing, ransomware, DDoS attacks) may have a greater impact on rail as the network relies more on technology than the road network. Given the reliance of rail infrastructure on technology, cyber-attacks could cause outages that endanger the safety of staff and disrupt freight flows.	A successful cyber-attack can have flow on effects that lasts for months, such as the freight industry reverting to manual processes, leading to decreased efficiency and prolonged disruptions. Network security may require recalibration after an attack to restore the road or rail supply chain network.
	As of July 2022, the National Terrorism Threat Advisory System considers an act of terrorism as probable. Extremist events pose a significant threat to the safety of people. Any damage to key infrastructure can cause prolonged closures and delays.	An extremist event can not only leave long-lasting infrastructure damage that requires rebuilding, but can also cause significant physical and psychological harm to those involved.

The Review notes that while road and rail supply chains generally prove resilient to more common risks, recent extreme events have highlighted an increasing need to build resilience into the future. Appendix C contains a detailed breakdown of how each of the nine key hazards could directly or indirectly impact the various physical components of road and rail supply chains.

The Review acknowledges there is a range of other relevant and emerging risks to road and rail supply chains that fall outside the scope of the Terms of Reference (see Appendix A). Given the potential for these risks to cause significant impacts on road and rail supply chains, Chapter 3.3 offers some commentary around these risks.

Case Study: Western Australia 2020 bushfires

Freight into Western Australia was bought to a standstill due to bushfires in early 2020. The fires blocked the Eyre Highway, a major freight route linking Western Australia to South Australia across the Nullarbor Plain. The widespread geographical footprint and dangers of bushfires made it unsafe for freight to travel along the 1,660 km stretch of highway. The highway was closed for twelve days in total, costing industry millions of dollars (Lucas, Hamlyn & de Silva 2020; Moussalli & Lucas 2020). As the only sealed road between Perth and Adelaide suitable for road freight, this led to supply chain disruptions into and out of southern Western Australia including in the city of Perth until the fires subsided (Lucas & Gubana 2020).

Case study: Cyber-attacks on freight operators

In a ransomware attack, hackers gain access to systems to observe how they operate, before shutting them down entirely and demanding payment for their release. In February 2020, Toll Group suffered a ransomware attack in what was described as the biggest cyber-attack on a supply chain to date. The attack resulted in the closure of many of Toll's delivery and tracking systems, forcing the company to move to a manual process. Toll saw weeks of delays and disruptions before the system was fully recovered, causing huge financial losses and delivery issues for customers. This event demonstrates the complexities and potentially disastrous impacts cyber-attacks can have on road and rail supply chains (Smith et al. 2020).

3.2 Other risks

The risks identified in this chapter are by no means exhaustive. Through research and stakeholder consultation, the Review has found there are a variety of other existing and emerging risks that are relevant to Australia's road and rail supply chain context, including:

- Pandemics;
- Shocks to the global supply chain (e.g. major conflicts, trade wars, industrial shutdowns);
- Space weather events;
- Issues relating to the increasing freight task;
- Workforce issues;
- Coordination, capacity and capability issues; and
- Other emerging and unknown risks.

While they do not reflect underlying physical issues with road and rail supply chain resilience, these are examples of risks that cannot be easily addressed as they are highly complex, unpredictable, and may be outside of government and industry control. Similarly, higher-intensity natural and human induced risks, and other unknown risks will continue to emerge.

The Review acknowledges that while these risks fall outside the scope of the Terms of Reference (see Appendix A), they can have significant impacts on road and rail supply chains and should be considered and addressed as part of improving road and rail supply chain resilience in the future. The Review also notes that while it has focused on road and rail supply chain resilience and risks through a domestic lens, there is merit in expanding future research to explore international supply chain resilience lessons learned, trends and innovations. A better understanding of successful or emerging international approaches to improving resilience could be beneficial when considering strategies at a national level.

Case study: The impact of the COVID-19 pandemic on domestic freight and labour

The COVID-19 pandemic saw unprecedented disruptions to the road and rail supply chain network. The Australian Government introduced international border restrictions and state and territory governments implemented movement restrictions individually to address the spread of COVID-19, impacting domestic freight movement (RBA 2021). To address the decline in freight activity across Australia's road and rail supply chain network caused by the early 2020 lockdowns, government collaboration with industry was able to successfully keep Australia's freight moving. The NCM's coordination role in addressing supply chain shortages, the National Heavy Vehicle Regulator's (NHVR) responsibilities around managing heavy vehicle access on the road network, and the Commonwealth's intervention to set up the National Freight Movement Code allowed freight to navigate jurisdiction lockdowns and keep Australia's freight network open while addressing associated COVID-19 risks to communities and the freight workforce (DITRDCA 2021a). As a result, freight movements were generally able to find stability, and in some cases saw slight growth in road freight.

A residual and continued impact of COVID-19 has seen workforce shortages as temporary migrants have had to leave the country and until recently, could not return easily. This issue has in part been considered in a commissioned report into Australia's Skilled Migration Program, noting some impacts remain (Parliament of Australia 2021). Similarly, COVID-19 continues to impact staffing levels, with major supermarket chains struggling to fill empty shelves as up to half of the freight workforce has been absent due to illness (Yang 2022).

The events of COVID-19 demonstrate that government and industry need to continue to remain flexible and adapt to unknown and emerging risks into the future. Government and industry stakeholders consulted as part of the Review noted benefits in encouraging the collective resilience conversation and coordination of action on strategic priorities around critical routes, transport capabilities and emerging risks at a national level. These include potential improvements to information sharing and understanding of the supply chain network, to ensure government and industry are prepared for, and have the tools to efficiently and effectively respond and recover in times of crisis, and build resilience before events occur.

3.3 Risk considerations and acceptance

As described in Chapter 3.1, risk profiles for road and rail supply chains are changing and will continue to do so into the future for both natural and human induced risks. Therefore, governance, risk frameworks and actions to plan for and address risks will have to accommodate these changing risk profiles.

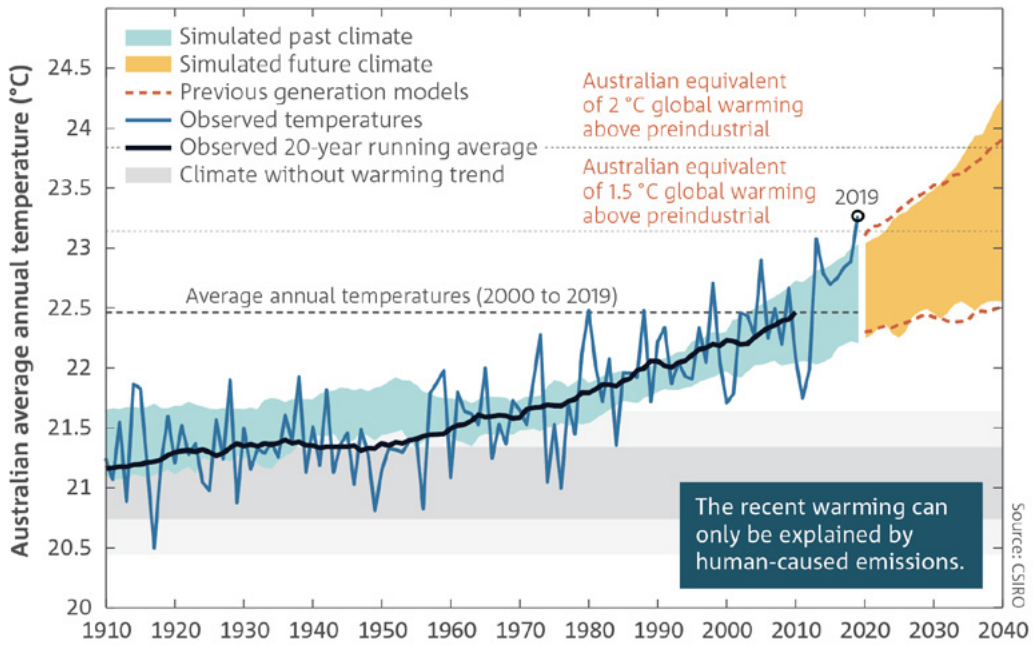
3.3.1 Risk considerations

Climate change

The financial cost of the changing climate is predicted to cost Australia's economy conservatively $1.2 trillion to 2060 (Deloitte 2021).

Australia's climate is changing (Figure 15), resulting in increasing frequency and severity of extreme weather events. The International Panel on Climate Change (IPCC 2022) predicts the number of hot days and heatwaves will rise, which increases bushfire risk. Australia's fire season has already grown by almost a month in the past forty years, highlighting the increased risk of bushfires occurring and impacting supply chains (Readfearn 2022).

Figure 15. Projections of Australia's climate forecast



Source: State of the Climate 2020 (Bureau of Meteorology n.d.)

Predicted increases in heavy rainfall intensity and events will increase the number of disruptions to road and rail supply chains through cyclones, storms and flooding (IPCC 2022). These impacts are already being felt across the freight network, with Figure 16 demonstrating the recent increase in ARTC rail network disruptions, particularly to the East-West rail corridor, due to more frequent natural disasters.

Figure 16. Rail disruptions following natural disasters are becoming more frequent

Note. This diagram does not capture all disruptions to the rail network between February 2020 to 2022.
Source: ARTC (2022)

The increase in frequency and severity of natural disasters will result in greater impacts to road and rail supply chains such as prolonged road closures, rail disruptions and the possibility of some regional LGAs becoming isolated or cut off for extended periods of time. This will see additional pressures put on all parts of the supply chain network, from input to storage through to distribution, as a climate-induced disruption at any point along the supply chain network can lead to many scenarios of empty shelves in supermarkets and inflated prices (Bartos 2022). Risk frameworks can benefit from acknowledging these increased risks when considering future supply chain governance to better understand and address them to prevent prolonged impacts in the short and long term. Similarly, these changes highlight the need to ensure there is a nationally consistent, long-term understanding of climate risks and scenarios to enable government and industry to respond to the potential impacts of climate change at a national and local level to inform land use and infrastructure planning and decision making.

Human induced risks

There were a reported 67,500 cyber-attacks in Australia in 2020–21. That equates to one cyber-attack every 8 minutes and represents an increase of 13 per cent from 2019–2020 (The Australian Cyber Security Centre (ACSC) 2021).

Human induced risks are also evolving. The ACSC reported an increase of 13 per cent of cyber-attacks in 2020–21 from 2019-20, reflecting the increasingly common nature of cyber-attacks. While the threat of these attacks is more apparent and potentially more damaging to rail routes given the continual electrification and technological advancement of the rail network (Australasian Railway Association 2017), they can occur to any part of the supply chain or mode and therefore, should be considered holistically across the whole supply chain network.

Extremist events are difficult to predict, especially when carried out by singular or small groups. While there is no current known threat, road and rail infrastructure such as hubs may be future targets given they are major thoroughfares. In particular, rail networks have unique features that make them inherently vulnerable to attack. For example, rail networks traverse dense urban landscapes which offer multiple target points for attacks, and freight networks often include vast rural stretches that are difficult to patrol and secure. Additionally, freight rail is used to transport hazardous materials and dangerous cargoes. Targeting such freight movement could lead to catastrophic damage to surrounding infrastructure. Attacks targeting passenger rail could also impact freight in areas with shared corridors.

Given the targeted damage and disruption posed by human induced risks, it has been noted by stakeholders, that risk frameworks and governance decisions would benefit from taking this into account when addressing their impacts.

3.3.2 Risk acceptance

Impact of evolving and emerging risks

As of July 2022, Greater Sydney has been subject to four record breaking flood events within the span of 18 months across 2021 and 2022 due to intense rain events such as the East Coast Low (Morton and Readfern 2022).

Risk profiles are constantly evolving, and it is difficult to predict the scale of these events with any certainty. These changes challenge currently accepted risk levels and highlight the need to reconsider risk benchmarks to adapt to this evolving environment. In the flood context, the uncertainty around risk considerations and management is reflected in the standard for considering flood impacts moving from a measurement of '1 in X years' towards using Average Exceedance Probability (AEP).

While current infrastructure planning and urban development guidelines generally ensure planning accounts for a 1% AEP event, recent floods have shown that this may not even be enough to account for greater frequency and severity of events, with the Chief Scientist of Queensland (2022) noting good future planning should consider more than just 1% AEP, such as planning for events with 0.5% AEP or less.

Risk profiles also vary with geography, with some areas more prone to certain risks than others. For example, cyclone and storm events are generally concentrated in Northern Australia (BOM n.d.). However, a changing climate is challenging this assumption, as reflected in parts of New South Wales recently experiencing disaster events in locations not usually prone to these risks (Morton and Readfern 2022). The changing geographical footprint of risk impacts should be acknowledged when considering current and future risk mitigation strategies. Furthermore, the chance of both road and rail infrastructure being disrupted simultaneously is a growing risk.

In addition to the increasing intensities and frequencies of identified risks, there are also other unknown risks that may emerge or occur at any given time (for example the COVID-19 pandemic and its subsequent impact on cross border supply chain routes). These risks are difficult to plan for and address as it is impossible to know when, where and how they may impact road and rail supply chains. To account for this uncertainty, risk frameworks, strategies and other governance decisions to address risk would benefit from being adaptable and accounting for a level of uncertainty.

There are existing engineering standards that are benchmarked by bodies such as Austroads and the Rail Industry Safety and Standards Board, that guide the development and design of road and rail infrastructure to ensure they achieve certain levels of resilience, with the details and specific benchmarks of these standards managed at different levels of government (Austroads 2022; Rail Industry Safety and Standards Board 2020). With the evolving risk environment, there could be benefit for these standards to consider and reflect the changing risk context in future iterations.

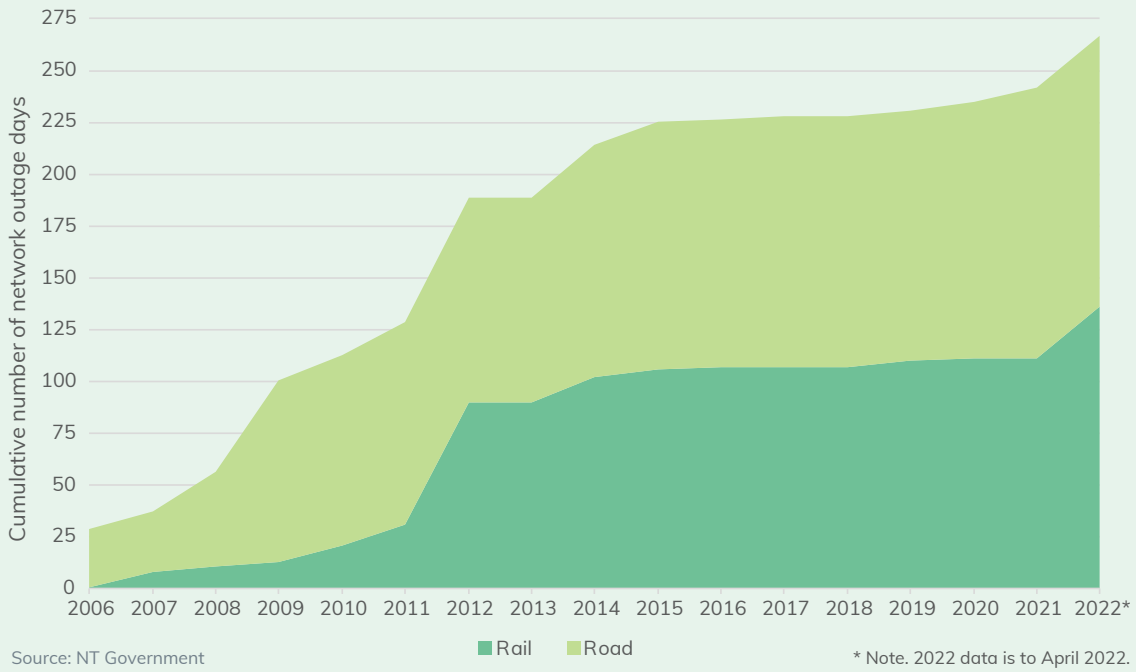
Case study: Cumulative number of road and rail network outage days in the Northern Territory

The Northern Territory has many routes to communities that serve as the only land-based connection (road). The territory's remote communities have no access to rail connections and in many cases, are inaccessible by road for up to six months of the year due to flooding. These communities are serviced by barge (if coastal) or by air in critical situations.

The Northern Territory has experienced an increasing number of outages across its road and rail network due to flooding or water over road events (Figure 17). Since 2006, the territory has seen a total of 266.7 days of outages across its road and rail network (130.7 and 136 days respectively). Northern Territory's road network currently experiences an average annual closure of 12 days, while its rail network experiences an average annual closure of 8 days.

In general, Northern Territory's national road network (Stuart, Victoria and Barkly Highways) is designed to a 1-in-20-year flood immunity. The recent increase in frequency and intensity of rainfall has resulted in its road network seeing more than double the number of days closed from 2020 to 2021. Similarly, 2022 has seen its rail network experience 25 days of outages to April – the highest number of annual rail outage days since 2012. These events highlight the impact of evolving risk profiles, which need to be factored into considerations when addressing and mitigating risks (and building resilience) in the short and long term.

Figure 17. Cumulative number of road and rail network outage days in the Northern Territory



Source: NT Government

* Note. 2022 data is to April 2022.

From response to preparation

> **Quality infrastructure must be defined in part by its ability to withstand climate change. Rising sea levels, extreme weather events and storm surges, high temperatures and heavy rainfall can all affect the lifespan of infrastructure (DFAT n.d.).**

Stakeholders consulted as part of the Review indicated that in light of this evolving context, there is demand for government and industry to consider how to be better prepared for risks rather than relying on responding as risk events arise. In planning for and building new or improving existing infrastructure, 'infrastructure for resilience' principles have been identified as a key consideration to ensure that assets are not only able to withstand risks in the immediate term, but are built and maintained to higher standards that can withstand longer term changes to the risk environment (Infrastructure Australia 2021b). Both industry and government stakeholders also noted national strategic frameworks such as the National Urban Freight Planning Principles, which brings together strategic transport and land use planning, can provide industry and government with a more consistent approach to resilience building.

Recent extreme weather events in western New South Wales and Victoria have illuminated the challenges associated with freight being carried on damaged roads, with some high use roads causing more damage to trucks that drive on them and resulting in growing supplier costs (Aeria 2022). Embedding principles in planning, maintenance and betterment (rebuilding public assets to a higher standard to be more resilient) to anticipate the wear and tear of infrastructure caused by increased use and damage from extreme weather events has been found to be a successful approach to addressing these issues (Queensland Reconstruction Authority n.d.). Maintaining these assets is critical to ensure that they remain resilient to natural disasters in the changing context described above. Concepts such as betterment avoid additional reconstruction costs in the future and in making public assets more resilient, will ensure the infrastructure that supply chains rely on remain intact in disaster events.

Generally, there is also a financial benefit to making infrastructure more resilient. Whilst data is scarce, early cost benefit analysis does reveal that it is highly likely that the cost of making infrastructure assets more resilient would be outweighed by the benefits of doing so (Hallegatte et al. 2019). More research could be done into the precise costs of making infrastructure resilient to guide decision making around future infrastructure investments (Proag & Proag 2014).

4. Risk framework

4.1 Best practice risk frameworks

The Review draws on a number of best practice risk framework examples to consider risks through a freight lens and inform the risk framework designed as part of the Review (see Chapter 4.2). Appendix E provides a brief summary of the best practice risk frameworks considered.

The need to define risk is the most ubiquitous element of risk frameworks. In the best practice frameworks selected, the Review identified the most common definition of risk is as a combination of likelihood and consequence. Risk consequence refers to the amount of damage a risk can cause to the supply chain or community, while risk likelihood refers to how likely that risk is to happen in a predetermined timeframe. This combination is then used to determine if a risk is critical, that is, it could have a very severe impact and could happen frequently, or on the other end of the spectrum, the risk is low as the risk is unlikely to occur very often, or its impact would not be considered severe. An adaptability rating is another common element of best practice risk frameworks, which refers to whether there are adaptability measures currently in place and the extent to which they could mitigate the identified risk. This is particularly useful to demonstrate where a particular risk has not been adequately prepared for and to identify where possible future adaptability measures should be targeted.

4.2 Resilience Review risk framework

The impact and consequence of risk events can never be fully or accurately predicted. Earlier chapters of this report highlight the difficulty in planning for and addressing risks due to uncertainty, including a changing natural environment and increasing technological development impacting the frequency and intensity of risks, and the emergence of new, unknown and unforeseeable risks. Risk impacts can also vary widely across Australia due to its various geographic characteristics. As a result, any framework designed to assess the level of risk in response to and in preparation for events should allow for flexibility to consider various risk profiles and geographical contexts.

To assess the risks to critical supply chain routes, the Review adopts a high-level risk framework that consists of a risk rating matrix (Table 4) that determines a risk rating based on likelihood and consequence.

Table 4. Risk rating matrix

		Consequence		
		Low	Medium	High
Likelihood	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

The analytical approach undertaken to establish this framework includes considering the:

- Freight policy context and range of potential hazards to road and rail supply chain routes; and
- Identification and prioritisation of risks.

In conceptualising the risk rating matrix, the definitions of likelihood and consequence in Table 5 have been used to define thresholds. Refer to Appendix C for a full list of risks assessed using this high-level risk framework.

Table 5. Definitions of likelihood and consequence to inform the risk rating matrix

Likelihood		Consequence	
Low	May occur once in a lifetime	**Low**	Impacts are largely confined to a **discrete region** with a duration of less than **two days**
Medium	Occurs a few times a generation	**Medium**	Impacts are **widespread** (geographically or population-wise) **for up to one week**; or Impacts are **localised** but disruption **extends longer than one week**
High	Occurs at least once per year	**High**	Impacts are **widespread** (geographically or population-wise) and it could take **greater than one week** to restore freight flows

4.3 Applying the resilience framework to critical supply chain routes

4.3.1 Methodology

In this section, the Review applies the risk framework set out in Chapter 4.2 to the closed intersection(s) of critical supply chain routes identified in Chapter 2.3 to calculate an overall vulnerability rating (Table 6) for each critical KFR to understand the impact of disruptions. The methodology used to calculate the vulnerability ratings of critical road and rail KFRs are stepped out below.

Table 6. Vulnerability rating descriptions for critical KFRs

Vulnerability rating	Road definition	Rail definition
Very high	Very high proportion of freight obstructed and very high risk of natural hazard disruption	Very high proportion of freight obstructed / very high proportion freight modal shift and very high risk of natural hazard disruption
High	High proportion of freight obstructed and high risk of natural hazard disruption	High proportion of freight obstructed / high proportion freight modal shift and high risk of natural hazard disruption
Medium	Medium proportion of freight obstructed and medium risk of natural hazard disruption	Medium proportion of freight obstructed / medium proportion freight modal shift and medium risk of natural hazard disruption
Low	Low proportion of freight obstructed and low risk of natural hazard disruption	Low proportion of freight obstructed / low proportion freight modal shift and low risk of natural hazard disruption
Very low	Very low proportion of freight obstructed and very low risk of natural hazard disruption	Very low proportion of freight obstructed / very low proportion freight modal shift and very low risk of natural hazard disruption

Road

The Review uses a vulnerability matrix (Table 7) to calculate a vulnerability rating for each modelled intersection closure, by considering the likelihood and consequence of a risk occurring and the adaptability of the route in response to the disruption from that risk. Each relevant critical road KFR is then assigned the vulnerability rating of its most vulnerable (highest rated) intersection.

Table 7. Vulnerability rating matrix for critical road KFR intersection closure points

		Impact on Freight				
		Very Low	Low	Medium	High	Very High
Risk Rating	Very Low	Very Low	Very Low	Low	Low	Medium
	Low	Very Low	Low	Low	Medium	High
	Medium	Low	Low	Medium	High	High
	High	Low	Medium	High	High	Very High
	Very High	Medium	High	High	Very High	Very High

The two metrics used in the vulnerability rating matrix are defined as follows:

- **Risk rating:**
  - Using the risk framework (see Chapter 4.2) the risk of cyclones and storms, seismicity, bushfire, flooding, extreme heat and landslides (hazards with exposure data available – refer to Appendix C) are evaluated at each intersection closure.
  - Each hazard was given a risk rating of 1-3 (representing low to high). Extreme heat is given a weighting of 0.5 to have a maximum risk rating value of 1.5, reflecting its comparatively minor consequences compared to other hazards as road and rail infrastructure is generally designed to tolerate heat.
  - All six risk ratings are summed to generate a total risk rating (with a maximum risk rating value of 16.5), which is then proportioned to assign a final risk rating (representing very low to very high).
- **Impact on freight:**
  - This metric refers to the proportion of obstructed commodities due to disruption, and is calculated by dividing the total volume of commodities obstructed due to intersection closure (as determined through TraNSIT), by the total volume of commodities that would usually traverse through that intersection under business as usual conditions. This proportion is then used to assign an impact on freight rating (representing very low to very high). This metric can also be referred to as an adaptability rating (see Chapter 4.1).

Rail

The Review uses a two-scenario approach for critical rail KFRs to determine a vulnerability rating for each route. The scenarios are based on the following conditions:

- Where rail looks to shift onto another rail route in response to a modelled intersection closure; or
- Where a critical rail KFR was unable to shift onto another rail route in response to a modelled intersection closure, freight was shifted to road.

Similar to critical road KFRs, the Review uses a vulnerability matrix (Table 8) to calculate a vulnerability rating for each modelled closure, by considering the likelihood and consequence of a risk occurring and the adaptability of the route in response to the disruption from that risk. Each critical rail KFR adopts the assigned vulnerability rating given to the modelled closure point as the route is only subject to a single point of disruption.

On average, the selected critical rail KFRs transport significantly higher volumes of freight through the modelled points of disruption (rail closure points carry on average nearly two times more freight volumes then modelled road closure points). Given the volume of freight impacted from rail disruptions, the vulnerability rating matrix is weighted differently to the road vulnerability rating matrix to reflect these impacts.

Table 8. Vulnerability rating matrix for critical rail KFR closure points

		Impact on Freight				
		Very Low	Low	Medium	High	Very High
Risk Rating	Very Low	Very Low	Very Low	Low	Medium	High
	Low	Very Low	Low	Medium	High	High
	Medium	Low	Medium	High	High	Very High
	High	Medium	High	High	Very High	Very High
	Very High	High	High	Very High	Very High	Very High

The two metrics used in the vulnerability rating matrix are defined as follows:

- **Risk rating:**
  - Using the risk framework (see Chapter 4.2) the risk of cyclones and storms, seismicity, bushfire, flooding, extreme heat and landslides (hazards with exposure data available – refer to Appendix C) are evaluated at each closure point.
  - Each hazard was given a risk rating of 1-3 (representing low to high). Extreme heat is given a weighting of 0.5 to have a maximum risk rating value of 1.5, reflecting its comparatively minor consequences compared to other hazards as road and rail infrastructure is generally designed to tolerate heat.
  - All six risk ratings are summed to generate a total risk rating (with a maximum risk rating value of 16.5), which is then proportioned to assign a final risk rating (representing very low to very high).
- **Impact on freight (where rail looks to shift onto another rail route):**
  - This metric refers to the proportion of obstructed commodities due to disruption, and is calculated by dividing the total volume of commodities obstructed due to closure point (as determined through TraNSIT), by the total volume of commodities that would usually traverse that intersection under business as usual conditions. This proportion is then used to assign an impact on freight rating (representing very low to very high). This metric can also be referred to as an adaptability rating (see Chapter 4.1).
- **Impact on freight (where rail looks to shift onto road):**
  - This metric captures the impact of mode shifting from rail to road (additional trailers on the road network to transport commodities that would otherwise travel by rail). This increase on the road network is then used to assign an impact on freight rating (representing very low to very high). This metric can also be referred to as an adaptability rating (see Chapter 4.1).

4.3.2 Assumptions and limitations

The methodology used in the Review provides a high-level assessment of the vulnerability of critical supply chain routes. However, there are a number of assumptions and limitations to this methodology including:

- The overall vulnerability score of a critical supply chain route is determined by the sum of the vulnerability of identified intersection closures. For road, there are up to three modelled intersections, while rail sees one modelled intersection closure. In the road scenarios, the busiest intersections of the critical routes in the TraNSIT model were chosen. The Review acknowledges that as a result, this modelling may not capture or represent the vulnerability of the whole freight route.
- This methodology only considers the amount of freight that is unable to be moved as a result of modelled intersection closures. The analysis does not consider time and cost to alternative routes or modes of transport when determining whether freight is obstructed as part of its overall vulnerability score. In a real-world scenario, time and cost will play a factor in determining whether alternative routes or modes are pursued, or if freight is obstructed. Similarly, there is limited data available around asset quality and alternative modes, which would also impact the overall vulnerability of a route, which is not considered in this analysis.

- In applying the risk framework to develop a risk rating, this methodology:
  - Assumes the greater the exposure of the hazard, the higher the likelihood of the hazard to occur and hence, a higher risk rating. Refer to Appendix C for a detailed breakdown of the definition of exposure score rankings from 1 to 3 for each hazard.
  - Adopts a scenario where all risks result in a medium consequence. Currently, there is limited data available to understand and evaluate the consequences of risk events on specific road and rail routes. This includes (as mentioned above) data on the condition and quality of road and rail assets.
- This analysis uses publicly available hazard data as it was readily accessible to the Review. As a result, there are a number of gaps and inconsistencies in natural hazard risk data. This affects the overall quality of evaluation and determination of hazard exposure scores for some intersections. Where an exposure score cannot be determined at the intersection, the exposure score of the nearest available route section is adopted. Similarly, where there are multiple exposure scores for any one hazard at the intersection, the highest exposure score value is adopted. The Review acknowledges there may be more suitable datasets such as non-public data or initiatives underway to improve and update data, which could provide more accurate analysis in the future.
- TraNSIT provides analysis on the impact of disruptions on all commodities on a critical KFR, as well as the impact on a subset of commodities considered essential. While it is important to understand the impact of disruptions to essential commodities, given the highly subjective and complex nature of defining what is considered essential, this methodology uses the impact of disruptions to all commodities when calculating the vulnerability of critical KFRs.
- The Review acknowledges that in reality, a disaster event may be widespread and impact alternative routes and modes in the same event. TraNSIT did not undertake scenario modelling of events where a natural or human induced hazard disrupted both road and rail routes simultaneously. There is opportunity for future work to explore complex scenarios to build a better understanding of the true impacts of hazards, including flow-on effects on the network.

There are opportunities to update and/or extend on the analysis of supply chain network resilience completed in the Review.

4.3.3 Analysis

A vulnerability rating was calculated based on the methodology outlined above (Chapter 4.3.1). Results of the analysis are found below (see Figure 18 and Table 9 for critical road KFRs; and Figure 19 and Table 10 for critical rail KFRs). A detailed summary of each critical KFR can be found in Appendix F.

Figure 18. Vulnerability rating for critical road KFRs

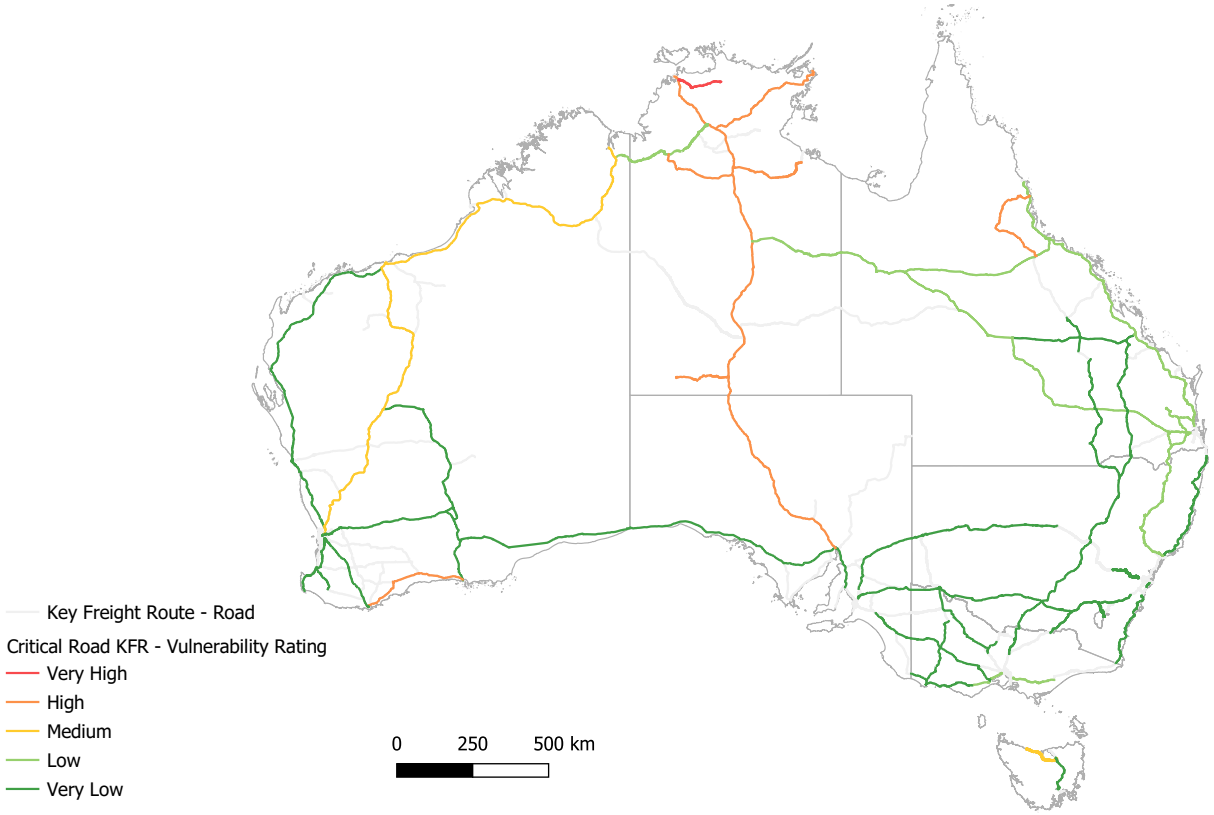


Table 9. Vulnerability rating for critical road KFRs

State	Critical KFR	Vulnerability Rating	Primary Risk/s (average rating of assessed intersections along KFR)	Commodities most impacted (% obstructed entire KFR)
NT	Arnhem Highway	Very High	Cyclones and Storms (high), Flooding (medium) and Bushfire (medium)	Cropping (100%), Wood Product (100%) and Processed Food (92.9%)
QLD	Gregory Development Road	High	Flooding (high) and Cyclones and Storms (medium)	Vehicles (99.8%), Cropping (94.8%) and Horticulture (90.6%)
WA	South Coast Highway	High	Flooding (medium) and Seismicity (low)	Mining (51.0%), Fuel (47.9%) and Cropping (28.4%)
NT	Buchanan Highway	High	Cyclones and Storms (medium) and Extreme Heat (medium)	Construction (92.4%) and Livestock (37.1%)
NT	Carpentaria Highway	High	Cyclones and Storms (medium), Bushfire (medium) and Extreme Heat (medium)	Fuel, General, Horticulture, Processed Food and Waste (all 100%)
NT	Central Arnhem Road	High	Cyclones and Storms (medium) and Bushfire (medium)	Construction, Cropping, Fuel, General, Horticulture, Livestock, Processed Food, Vehicles, Waste and Wood Product (all 100%)
NT	Lasseter Highway	High	Flooding (high) and Extreme Heat (medium)	Livestock (31.3%), Fuel (20.0%) and Processed Food (16.9%)
NT*	Stuart Highway	High	Flooding (medium) and Extreme Heat (medium)	Construction (70.3%), Livestock (48.3%) and Processed Food (40.7%)
WA	Great Northern Highway	Medium	Flooding (medium) and Seismicity (low)	Mining (42.7%), Construction (11.5%) and Fuel (6.4%)
Tas.	Bass Highway	Medium	Seismicity (low) and Extreme Heat (low)	Livestock (63.6%), Horticulture (53.6%) and Vehicles (52.2%)
NSW	New England Highway	Low	Flooding (high), Seismicity (low) and Extreme Heat (low)	Waste (2.7%), Fuel (0.8%) and Processed Food (0.6%)

State	Critical KFR	Vulnerability Rating	Primary Risk/s (average rating of assessed intersections along KFR)	Commodities most impacted (% obstructed entire KFR)
Vic.	Princes Freeway East	Low	Flooding (high) and Seismicity (medium)	Waste (13.8%), Vehicles (0.8%) and Fuel (0.4%)
QLD	Brisbane Valley Highway	Low	Flooding (high) and Landslide (medium)	Wood Product (4.4%), Fuel (2.5%) and Cropping (0.5%)
QLD	Bruce Highway	Low	Flooding (high) and Cyclones and Storms (medium)	Construction (1.2%), Waste (1.2%) and Livestock 0.4%
QLD	Cunningham Highway	Low	Flooding (high) and Landslide (low)	Waste (7.3%), Fuel (2.4%) and Cropping (1.0%)
QLD	D'Aguilar Highway	Low	Flooding (high) and Cyclones and Storms (medium)	Vehicles (12.2%), General (9.0%) and Waste (5.3%)
QLD	Flinders Highway	Low	Flooding (high) and Cyclones and Storms (medium)	Livestock (8.5%) and Waste (5.3%)
QLD	Landsborough Highway	Low	Flooding (medium) and Extreme Heat (medium)	Waste (33.3%), Fuel (2.3%) and Livestock (0.4%)
QLD	Warrego Highway	Low	Flooding (medium) and Extreme Heat (low)	Fuel (1.4%), Wood Product (0.3%) and General (0.2%)
NT*	Barkly Highway	Low	Flooding (high) and Extreme Heat (medium)	Mining (94.4%), Fuel (4.5%) and Livestock (2.4%)
NT*	Victoria Highway	Low	Cyclones and Storms (medium) and Bushfire (medium)	Waste (100%), Livestock (21.0%) and Fuel (10.3%)
NSW	Barrier Highway	Very Low	Flooding (medium) and Seismicity (low)	Livestock (0.2%), Processed Food (0.4%) and Horticulture (0.1%)
NSW	Carnarvon Highway	Very Low	Flooding (high) and Extreme Heat (medium)	Waste (11.1%), Fuel (8.3%) and General (0.8%)
NSW	Great Western Highway	Very Low	Flooding (high) and Seismicity (low)	Waste (1.1%), General (0.7%) and Wood Product (0.4%)
NSW	Hume Highway	Very Low	Flooding (high) and Seismicity (low)	Construction (0.7%), Livestock (0.2%) and Fuel (0.1%)
NSW	Newell Highway	Very Low	Flooding (high) and Extreme Heat (low)	Waste (1.7%), Construction (1.5%) and Livestock (0.1%)
NSW	Pacific Highway	Very Low	Flooding (high) and Cyclones and Storms (low)	Waste (1.4%), Cropping (0.6%) and Fuel (0.3%)
NSW	Princes Highway NSW	Very Low	Flooding (high) and Seismicity (low)	Construction (21.3%), Waste (2.9%) and Horticulture (0.2%)
NSW	Sturt Highway	Very Low	Flooding (high), Seismicity (low) and Extreme Heat (low)	Mining (2.2%), Cropping (2.0%) and Livestock (0.6%)
Vic.	Calder Highway	Very Low	Flooding (medium) and Extreme Heat (low)	Waste (2.6%), General (0.3%) and Cropping (0.1%)
Vic.	Dukes Highway	Very Low	Seismicity (low) and Extreme Heat (low)	Wood Product (0.1%), Cropping (0.01%) and Livestock (0.02%)
Vic.	Goulburn Valley Highway	Very Low	Flooding (high), Seismicity (low) and Extreme Heat (low)	Construction (60.3%), Waste (4.5%) and Fuel (1.6%)
Vic.	Henty Highway	Very Low	Flooding (low), Seismicity (low) and Extreme Heat (low)	Waste (6.1%), Cropping (0.1%) and Fuel (0.1%)
Vic.	Princes Freeway West	Very Low	Flooding (high), Seismicity (low) and Extreme Heat (low)	Waste (2.1%) and Cropping (0.05%)
Vic.	Princes Highway Vic	Very Low	Flooding (medium), Seismicity (low) and Extreme Heat (low)	Livestock (0.4%), Cropping (0.3%) and Fuel (0.04%)
Vic.	Western Highway	Very Low	Flooding (low), Seismicity (low) and Extreme Heat (low)	Waste (3.1%), Vehicles (1.5%) and Wood Product (0.4%)
QLD	Capricorn Highway	Very Low	Flooding (high) and Extreme Heat (low)	Waste (9.5%), General (1.3%) and Processed Food (0.6%)
QLD	Gregory Highway	Very Low	Flooding (high) and Extreme Heat (medium)	Vehicles (20.0%), Fuel (14.7%) and Waste (6.7%)
QLD	Leichhardt Highway	Very Low	Flooding (high) and Extreme Heat (low)	Waste (5.3%), Fuel (3.6%) and Livestock (0.1%)
SA	Augusta Highway	Very Low	Flooding (high) and Extreme Heat (low)	Construction (3.0%), Fuel (1.1%) and Vehicles (0.3%)

State	Critical KFR	Vulnerability Rating	Primary Risk/s (average rating of assessed intersections along KFR)	Commodities most impacted (% obstructed entire KFR)
SA	Eyre Highway	Very Low	Flooding (medium) and Extreme Heat (low)	Waste (17.9%), Fuel (0.5%) and Cropping (0.03%)
WA	Albany Highway	Very Low	Flooding (medium) and Seismicity (low)	Vehicles (45.8%), Construction (14.5%) and General (6.1%)
WA	Brand Highway	Very Low	Flooding (medium) and Extreme Heat (low)	Construction (8.7%), Waste (4.5%) and Livestock (2.2%)
WA	Bussell Highway	Very Low	Flooding (medium) and Seismicity (low)	Waste (2.2%), Livestock (0.2%) and Horticulture (0.001%)
WA	Coolgardie - Esperance Highway	Very Low	Seismicity (low) and Extreme Heat (low)	Mining (8.5%), Vehicles (6.7%) and Waste (6.7%)
WA	Goldfields Highway	Very Low	Seismicity (medium) and Extreme Heat (medium)	Horticulture (87.6%), Construction (34.4%) and Processed Food (20.1%)
WA	Great Eastern Highway	Very Low	Flooding (low) and Seismicity (low)	Waste (16.9%) and Fuel (0.7%)
WA	North West Coastal Highway	Very Low	Cyclones and Storms (medium) and Extreme Heat (medium)	Processed Food (11.7%), General (10.2%) and Horticulture (9.9%)
WA	South Western Highway	Very Low	Flooding (medium), Seismicity (low) and Extreme Heat (low)	Construction (4.2%), Fuel (2.2%) and Processed Food (0.8%)
Tas.	Midland Highway	Very Low	Seismicity (low) and Extreme Heat (low)	Vehicles (5.1%), Construction (5.0%) and Waste (2.3%)
ACT	Barton Highway	Very Low	Flooding (high) and Seismicity (medium)	Waste (1.5%), Processed Food (0.1%) and Livestock (0.07%)
ACT	Monaro Highway	Very Low	Flooding (high) and Seismicity (medium)	Waste (1.2%)

* Note. The TraNSIT analysis allocates the Stuart Highway to South Australia, the Barkly Highway to Queensland, and the Victoria Highway to Western Australia. The Review allocates these routes to the Northern Territory.

Figure 19. Vulnerability rating for critical rail KFRs

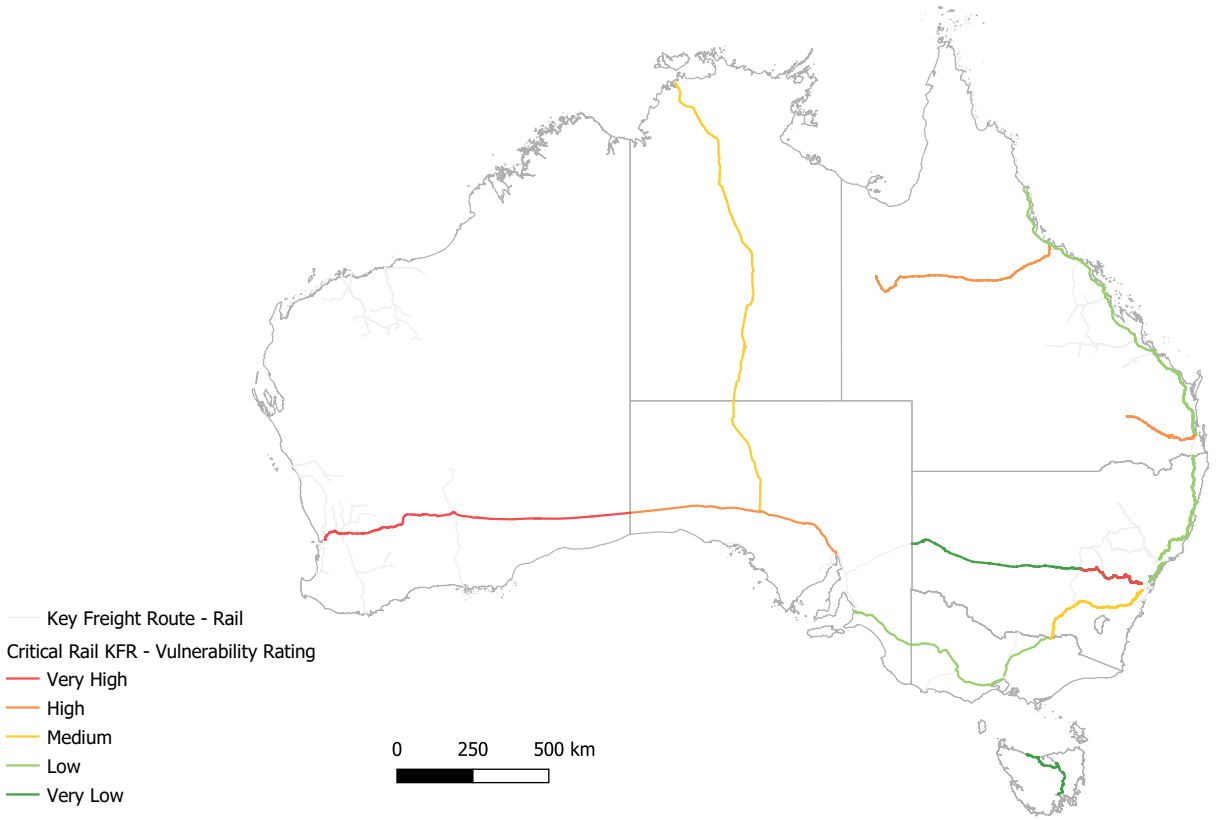


Table 10. Vulnerability rating for critical rail KFRs

State	Critical KFR	Vulnerability Rating	Primary Risk/s (rating of assessed disruption point along KFR)	Change in freight along alternative road routes (% increase)
WA*	WA Transcontinental line	Very High	Flooding (high) and Seismicity (medium)	Great Eastern Highway (271%)
NSW	NSW Main West Line	High	Seismicity (low) and Extreme Heat (low)	Alternative rail route available for 19% of freight. Remaining (mining) completely obstructed.
QLD	Qld Great Northern Line	High	Cyclones and Storms (high) and Bushfire (low)	Flinders Highway (92%)
QLD	Queensland Western System	High	Seismicity (low) and Extreme Heat (low)	Warrego Highway (107%)
SA*	SA Transcontinental line	High	Seismicity (low) and Extreme Heat (medium)**	Eyre Highway (133%)
NSW	NSW Main South Line	Medium	Flooding (high) and Seismicity (medium)	Alternative rail route available for 56% of freight. Remaining (mining) completely obstructed.
NT	The Ghan	Medium	Cyclones and Storms (medium) and Extreme Heat (medium)	Stuart Highway (53%)
NSW	NSW North Coast Line	Low	Bushfire (low), Seismicity (low) and Extreme Heat (low)	Pacific Motorway (22%)
Vic.	Melbourne - Adelaide Main line	Low	Flooding (high), Seismicity (low) and Extreme Heat (low)	Western and Dukes Highway (32%)
Vic.	Victoria North East Line	Low	Flooding (high) and Extreme Heat (low) and Seismicity (low)	Hume Highway (25%)
QLD	Queensland North Coast Line	Low	Cyclones and Storms (medium) and Seismicity (low)	Bruce Highway (3%)
NSW	NSW Main Broken Hill Line	Very Low	Extreme Heat (medium)	Alternative rail route available for all freight.
Tas.	Tasmania Main Line	Very Low	Seismicity (low) and Extreme Heat (low)	Midland Highway (3.6%)

* Note. For the purpose of the TraNSIT analysis, the East-West rail corridor has been divided into separate routes such as the WA Transcontinental and SA Transcontinental lines, based on their state alignment. The Review refers to the East-West rail corridor to capture both these routes more broadly under one umbrella term.

** The data used in the Review to undertake its risk assessment did not show flooding as a primary risk.

Of the 65 critical KFRs assessed, eight critical road KFRs and five critical rail KFRs were identified by the Review as having a vulnerability rating of high or very high (Figure 20 and Figure 21). For further details of each route (and other routes), refer to Appendix B and Appendix F.

Figure 20. Critical road KFRs with high and very high vulnerability ratings

Arnhem Highway: Vulnerability rating: Very High

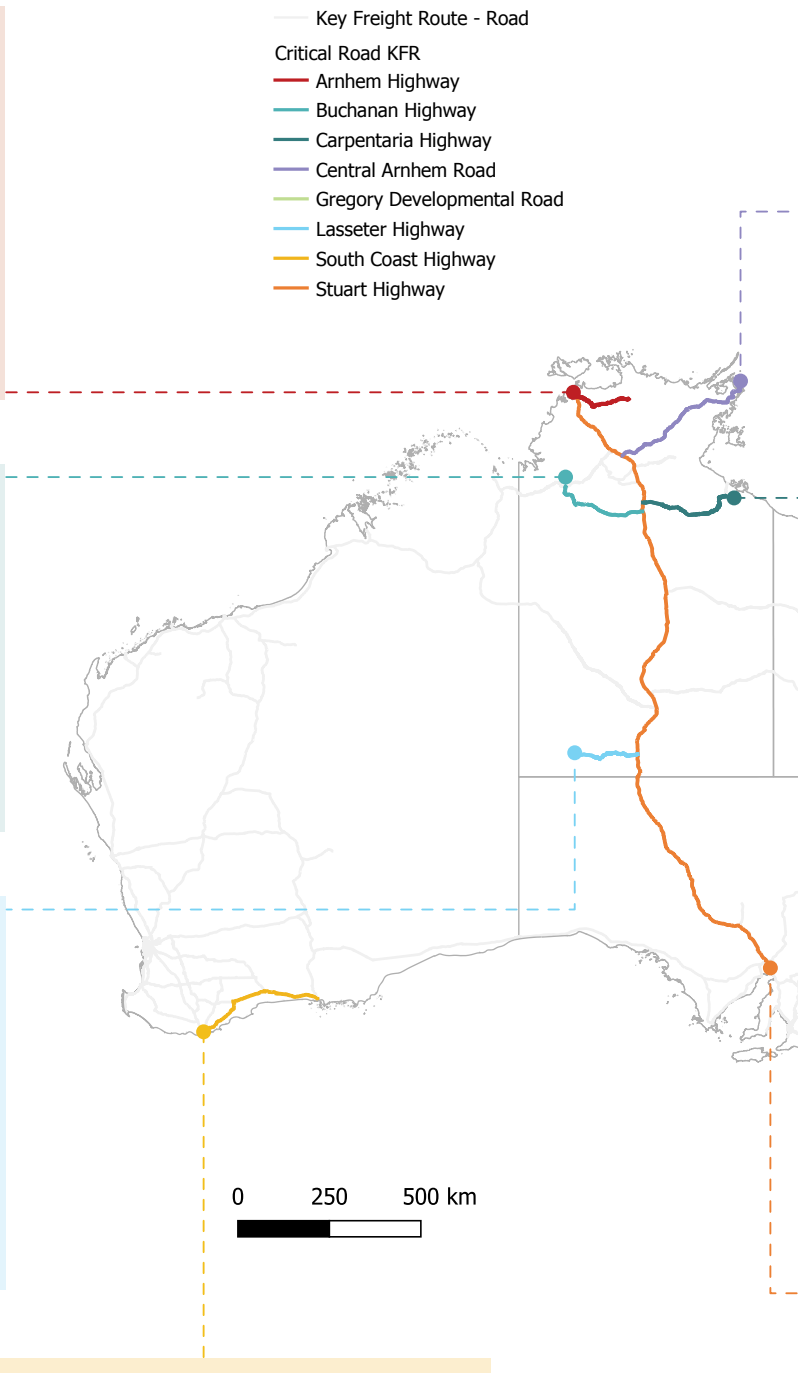
The Northern Territory's 224km Arnhem Highway connects Darwin to northwestern LGAs. Construction transport represents 55 per cent of the total freight task. Importantly, the KFR supports the movement of processed food and fuel to communities, and cropping and livestock to and from enterprises. The KFR passes through three LGAs and supports supply chain paths for over 59 LGAs. The three intersections assessed are primarily exposed to cyclones and storms, flooding and bushfires. At the Point Stuart Road and Oenpelli Road intersections, disruptions can result in 100 and 98 per cent of freight respectively completely obstructed.

Buchanan Highway: Vulnerability rating: High

The Northern Territory's 395km Buchanan Highway connects the Stuart Highway to the Victoria Highway. Livestock transport represents 60 per cent of the total freight task, with construction the only other significant freight along the route. The KFR passes through three LGAs and supports supply chain paths for over 50 LGAs. The three intersections assessed are primarily exposed to cyclones and storms and extreme heat. At the Buntine Highway and Victoria Highway intersections, disruptions can result in 80 and 99 per cent of freight respectively completely obstructed.

Lasseter Highway: Vulnerability rating: High

The Northern Territory's 245km Lasseter Highway connects LGAs from the Stuart Highway west to Yulara. Fuel transport represents 50 per cent of the total freight task, with the majority of movements from depots to stations. Livestock represents 30 per cent to the total freight task. Importantly, movements to supermarkets (including processed food and general freight) adds 10 per cent to the total freight task. The KFR passes through two LGAs and supports supply chain paths for over 38 LGAs. The three intersections assessed are primarily exposed to flooding and extreme heat. At the Mulga Park Road intersection, disruptions can result in 98 per cent of freight completely obstructed.

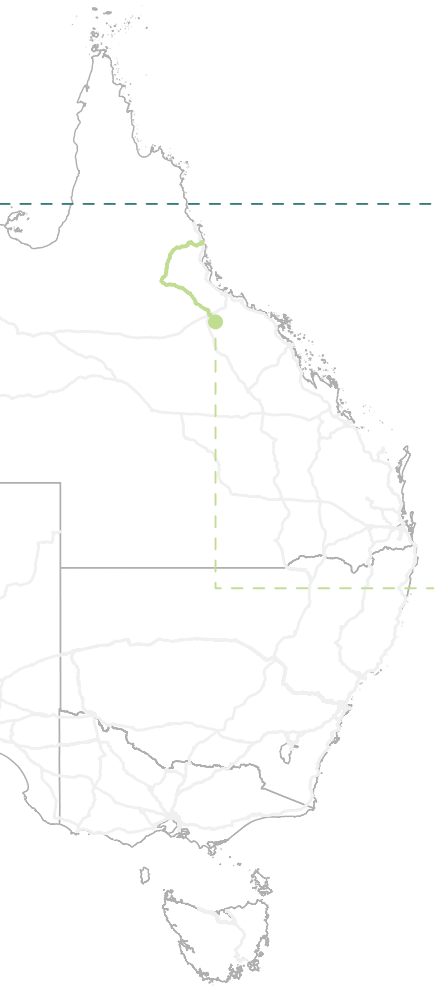


South Coast Highway: Vulnerability rating: High

Western Australia's 467km South Coast Highway connects LGAs from Albany to Esperance. Cropping transport represents 80 per cent of the total freight task, with a large proportion of movements from properties to silos and on to ports. Wood products represent 10 per cent of the total freight task, with a large proportion of movements to ports. The KFR passes through four LGAs and supports supply chain paths for over 181 LGAs. The three intersections assessed are primarily exposed to flooding and seismicity. At the Harbour Road intersection, disruptions can result in 100 per cent of freight completely obstructed.

Central Arnhem Road: Vulnerability rating: High

The Northern Territory's 675km Central Arnhem Road connects LGAs between the Stuart Highway and Nhulunbuy in the northeast. Construction transport and livestock represent 50 and 12 per cent of the total freight task respectively. Processed food and fuel represent 10 per cent of the total freight task. The KFR passes through five LGAs and supports supply chain paths for over 34 LGAs. The one intersection assessed (at the Stuart Highway) is primarily exposed to cyclones and storms and bushfires, and disruptions can result in 100 per cent of freight completely obstructed.



Carpentaria Highway: Vulnerability rating: High

The Northern Territory's 367km Carpentaria Highway connects LGAs between the Gulf of Carpentaria to the Stuart Highway. Fuel transport represents 75 per cent of the total freight task, with critical links from ports to depots and mines. Livestock and mining represent 20 per cent of the total freight task. The KFR passes through two LGAs and supports supply chain paths for over 48 LGAs. The two intersections assessed are primarily exposed to cyclones and storms, bushfires and extreme heat. At the Stuart Highway and Tablelands Highway intersections, disruptions can result in 78 and 82 per cent of freight respectively completely obstructed.

Gregory Development Road: Vulnerability rating: High

Queensland's 549km Gregory Development Road connects LGAs from Charters Towers to Cairns via an inland route providing access to the Atherton Tablelands. Cropping, fuel, horticulture and livestock each represent 15 per cent to the total freight task, while wood products represent 10 per cent. Importantly, the KFR provides access to markets for primary produce, with 40 per cent of all movements originating at a property. The KFR passes through five LGAs and supports supply chain paths for over 143 LGAs. The three intersections assessed are primarily exposed to cyclones and storms and flooding. At the Palmerston Highway and Lynd Junction intersections, disruptions can result in 88 and 97 per cent of freight respectively completely obstructed.

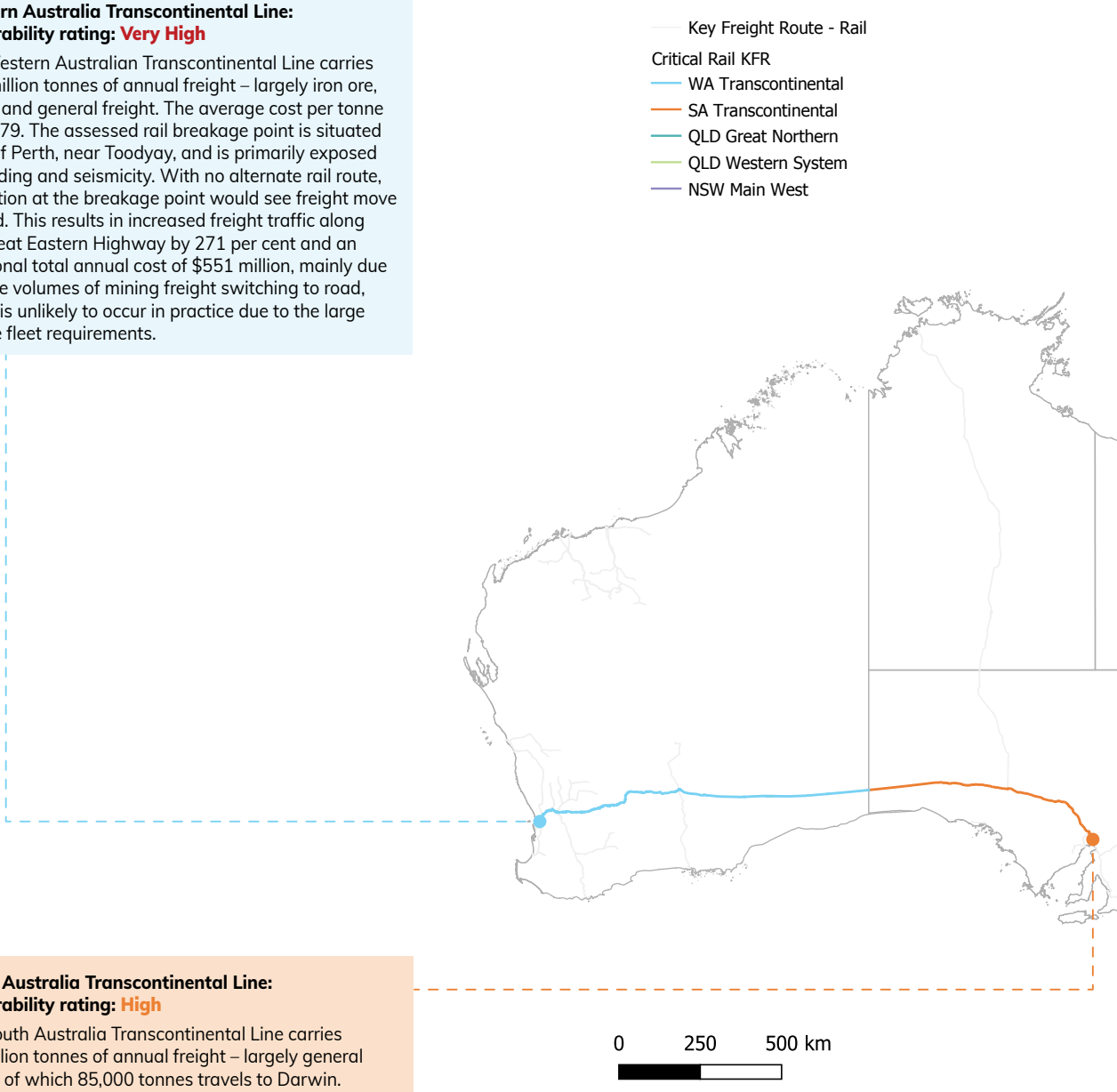
Stuart Highway: Vulnerability rating: High

The 2,781km Stuart Highway is a critical north – south route that runs between Port Augusta in South Australia and Darwin in the Northern Territory via Alice Springs. Fuel transport represents 32 per cent of the total freight task. Mining and livestock each represent 20 per cent of the total freight task. 40 per cent of movements along the KFR originate at a property or port, and 20 per cent are destined to a port. The KFR passes through 16 LGAs and supports supply chain paths for over 283 LGAs. The three intersections assessed are primarily exposed to flooding and extreme heat. At the Victoria Highway intersection, disruptions can result in 100 per cent of freight completely obstructed.

Figure 21. Critical rail KFRs with high and very high vulnerability ratings

Western Australia Transcontinental Line:
Vulnerability rating: Very High

The Western Australian Transcontinental Line carries 12.7 million tonnes of annual freight – largely iron ore, grains and general freight. The average cost per tonne is $47.79. The assessed rail breakage point is situated west of Perth, near Toodyay, and is primarily exposed to flooding and seismicity. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Great Eastern Highway by 271 per cent and an additional total annual cost of $551 million, mainly due to large volumes of mining freight switching to road, which is unlikely to occur in practice due to the large vehicle fleet requirements.

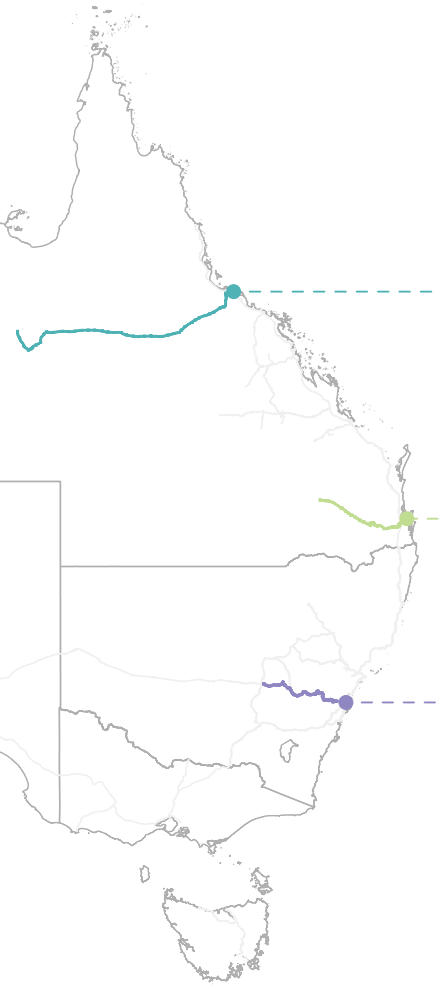


South Australia Transcontinental Line:
Vulnerability rating: High

The South Australia Transcontinental Line carries 2.2 million tonnes of annual freight – largely general freight of which 85,000 tonnes travels to Darwin. The average cost per tonne is $194.21. The assessed rail breakage point is situated northwest of Port Augusta, near Pimba, and is primarily exposed to seismicity and extreme heat. While flooding examples along the KFR were noted, flooding exposure data provided to the Review did not identify this as a primary risk and therefore, was not used to calculate the vulnerability rating. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Eyre Highway by 133 per cent and an additional total annual cost of $445 million.

Queensland Great Northern Line: Vulnerability rating: High

The 950km Queensland Great Northern Line carries 2.3 million tonnes of annual freight – largely minerals, and connects to numerous connectors and terminals. The average cost per tonne is $41.45. The KFR also serves as a cattle service. The assessed rail breakage point is situated west of Townsville on the Mt Isa to Townsville route, and is primarily exposed to cyclones & storms and bushfires. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Flinders Highway by 92 per cent and an additional total annual cost of $45 million.



The Queensland Western System: Vulnerability rating: High

The 300km Queensland Western System Line carries 5.1 million tonnes of annual freight – largely coal, and connects the KFR and other lines servicing southwest Queensland to Brisbane. The average cost per tonne is $20.55. The assessed rail breakage point is situated west of Brisbane in the Lockyer Valley, and is primarily exposed to seismicity and extreme heat. With no alternate rail route, disruption at the breakage point would see freight move to road. This results in increased freight traffic along the Warrego Highway by 107 per cent (mostly eastbound) and an additional total annual cost of $39 million.

New South Wales Main West Line: Vulnerability rating: High

The 500km New South Wales Main West Line carries 8.2 million tonnes of annual freight – largely mining and general freight. The average cost per tonne is $40.77. The assessed rail breakage point is situated west of Sydney, near Orange, and is primarily exposed to seismicity and extreme heat. Disruption at the breakage point would see freight take an alternative rail route. While the majority of commodity types would see minimal impact, 96 per cent (6.6 million tonnes) of mining freight (which makes up 81 per cent of total freight volumes) would be completely obstructed.

Case Study: East-West rail corridor flooding

Using the Review's risk framework, the East-West rail corridor was assessed as having a very high and high vulnerability rating in the Western Australian and South Australian portions of the route respectively.

Extensive flooding in January and February 2022 forced the closure of the East-West rail corridor for 24 days, causing widespread disruptions to supply chains and financial issues for government and industry across the country (Perpitch 2022).[5] For the remote town of Coober Pedy, the Australian Defence Force (ADF) was enlisted to airdrop essential commodities into the town, as there was no viable alternative route to provide supplies. The ADF airdropped over 100 tons of food and essential supplies into the outback town for its residents before flood waters receded and the road and rail supply chain routes could reopen (Defence 2022).

WA's Department of Transport noted shipping was able to replace approximately 15 to 20 per cent of volumes typically moved through the state via the East-West rail corridor, though with a delay of a few weeks and the consolidation of volumes. Road was able to move around 10 per cent of volumes. At the time, supermarket companies estimated they needed at least 60 per cent of their usual rail supplies to maintain standard supply. Without the ability to move freight onto ships, the situation could have been worse for communities in southern WA.

The NCM coordinated ways to reduce the impacts to Western Australia by enabling the establishment of a 'land bridge'. The establishment of the land bridge, in collaboration with the NHVR, and transport industry CEOs provided greater road freight capacity between Adelaide and Kalgoorlie while options for additional sea freight were considered and then actioned.

To resolve the supply of water purification chemicals transport to the east, an essential element to sanitise flood affected drinking-water reserves, the NCM coordinated with the South Australian Government and industry to enable supplies to be transported to the eastern states.

The consequences of this event highlight the important roles of alternative transport modes such as aviation and maritime in response to times of need, and should be considered as part of increasing the resilience of the supply chain network as a whole moving forward.

Case study: Hunter Valley flooding

While the Hunter Valley Corridor Network was not directly assessed within the Review, it does not mean that these routes (along with others not assessed) are not important to Australian communities.

In July 2022, an East Coast Low brought record rainfalls to the Hunter Valley (ABC 2022), flooding parts of the road and rail network and disrupting passenger and freight movement along its rail corridors. The Hunter Valley Corridor rail network predominately carries coal to power stations in New South Wales and to the Port of Newcastle for export. Grain and other freight for local communities are also moved on the network.

In June 2022, the New South Wales Government granted emergency powers to secure coal supplies to ensure sufficient stocks to provide energy, highlighting the criticality of coal as a commodity (The Guardian 2022). The Review notes that for both the Hunter and the Bowen Basin, switching coal transportation from rail to road (assuming the road fleet was available) would lead to over 1,000 per cent increase in heavy vehicle freight along regional freight routes, which would lead to significant congestion.

The section of rail between Sandgate and Maitland affects movement on both the North Coast Line and Hunter Valley Line. Stakeholders consulted as part of the Review noted flooding at Maitland can take out operations on both lines simultaneously, impacting freight movements between Sydney and Brisbane; and from north west New South Wales to Newcastle, power stations and Sydney. Until Inland Rail is operational, there does not appear to be sufficient redundancy available in the supply chain to address closures of the North Coast Line, particularly where the Pacific Highway may be concurrently affected by the same events.

5 The Review acknowledges while the same flooding events impacted road, the purpose of this case study is to illustrate the flooding impact on rail.

5. Stocktake of initiatives that address road and rail supply chain resilience

5.1 Current initiatives

The Review has identified a range of existing initiatives by government and industry intended to contribute to the resilience of road and rail supply chains through desktop research and stakeholder consultation. Initiatives vary from strategic guidance at a broader national level (such as the NFSCS, National Urban Freight Planning Principles, National Reconstruction Fund and National Rail Manufacturing Plan), commonly lead by the Australian Government, to more targeted location-specific work, commonly led by states and territories (such as infrastructure investments that build new or upgrade existing parts of the freight network). There are also existing engineering standards that are benchmarked by bodies such as Austroads and the Rail Industry Safety and Standards Board, that guide the development and design of road and rail infrastructure to ensure they achieve certain levels of resilience.

Identified initiatives are broadly categorised into:

- New infrastructure and infrastructure renewal/improvement;
- Governance and coordination;
- Data and insights; and
- Capacity building.

See Appendix G for a list of identified initiatives. Note that this attachment should not be considered an exhaustive list of initiatives that may improve supply chain resilience. The stocktake also does not attempt to document the large number of catchment-specific floodplain management strategies, but rather captures this type of intervention as a single line item; nor does it document all-natural hazard resilience initiatives commissioned by public and private sector organisations, as these are often held confidentially. However, it does capture initiatives led by state/territory transport and infrastructure agencies where these are publicly available and/or discovered through this stocktake process.

The following case studies are examples of existing resilience initiatives across government.

Case study: National Disaster Risk Reduction Framework and National Action Plans

The NDRRF (2018) is the Commonwealth's overarching disaster risk reduction framework for natural hazards. As the domestic implementation mechanism for the Sendai Framework for Disaster Risk Reduction 2015-2030, it establishes Australia's 2030 vision, outlines a coordinated, systemic approach to reducing disaster risk, and guides national efforts across four priority areas to proactively reduce existing disaster risk and prevent the creation of new risk. The four priority areas are: understand disaster risk; accountable decisions; enhanced investment; and governance, ownership and responsibility. While it covers risk reduction in general, it acknowledges Australia's reliance on reliable transport networks and its complex interactions with other asset classes and functions. The NDRRF will be reviewed in 2023.

One mechanisms to progress action on the NDRRF are through National Action Plans. The first National Action Plan (2020) outlined a range of initiatives aligned to the NDRRF that were already underway. Building on this, the National Emergency Management Agency (NEMA) is currently working closely with the Australian Institute for Disaster Resilience and consulting with stakeholders, including all levels of government, industry and communities to develop the second National Action Plan, which will be more strategic, forward looking and action oriented. It is expected to be completed by the end of 2022.

Case study: National Freight and Supply Chain Strategy and National Action Plan

The Commonwealth's NFSCS (2019) is a coordinated national approach to freight by government and industry, covering all transport modes to 2040 and beyond. This is an example of a transport and supply chain specific initiative designed to position Australia's multimodal freight supply chains to meet the forecasted freight demand, as well as significant system pressures and environmental factors. The first iteration of the NFSCS sets out four key areas of the freight network – infrastructure investment; supply chain efficiency; planning, coordination and regulation; and location and performance data. These key areas form the basis of a nationally integrated and planned freight system, and is driven by its associated National Action Plan, which identifies 13 actions, the first of which is to ensure that supply chains are serviced by resilient and efficient key freight corridors, precincts and assets. The NFSCS will undergo a 5-year review in 2024, where the action areas will be reviewed and updated as appropriate.

Case study: Inland Rail

Inland Rail is a 1,700km rail project that will connect Melbourne and Brisbane via regional Victoria, New South Wales and Queensland (ARTC n.d.). Almost 70 per cent of freight carried on Inland Rail will be for domestic use, including household goods and groceries produced in Australia and consumed in its major cities. Once complete, Inland Rail will improve supply chain resilience by providing a second link between Queensland and the southern states. As the rail distance between Melbourne and Brisbane will be reduced by 200km, costs for freight travelling between the cities could be reduced by $10/per tonne in comparison with the current coastal rail route. The current coastal rail route will also see a reduction in congestion, resulting in increased capacity for other passenger and freight services, particularly around Sydney's busy passenger rail network.

Case study: State Infrastructure Strategies and Plans

State Infrastructure Strategies and Plans are examples of governance and coordination initiatives seeking to foster the enabling environment to better anticipate, manage and adapt to risks. The initiatives set strategic priorities for each jurisdiction's infrastructure investment pipeline, with resilience becoming an increasingly prominent theme. For example, New South Wales' State Infrastructure Strategy 2022-2042 acknowledges the need to ensure New South Wales' existing and future infrastructure is resilient to natural hazards and human related threats. Victoria's Infrastructure Strategy 2021-2051 includes a priority to embed resilience, including recommendations to improve critical infrastructure information flows and build back better after emergencies.

Case study: Resilience initiatives in Tasmania

At a state level, jurisdictions are each undertaking various action to address the issues they face around transport and supply chain resilience. For example, stakeholder consultation found the Tasmanian Department of State Growth is undertaking a number of initiatives to ensure roads remain resilient, including managing an emergency risk register and identifying critical points of failure and development opportunities to improve its network. It is also taking steps to ensure new assets such as bridges are built to resist worse-case scenario modelling, legacy infrastructure is upgraded to be as resilient as practically possible, and put in place emergency plans in the event of failures within the network leading to significant freight and transport disruptions.

Similarly, TasRail (2022) is currently delivering its network capital renewal program, with a focus on removing single points of failure (SPF) that can lead to derailments and disrupt Tasmania's key supply chains. SPF have numerous underlying causes including near-life or expired rail and sleepers that do not meet current standards, poor drainage, storm surges in coastal areas and successive days of high track temperatures. This initiative is reducing the number of SPF across the network to ensure supply chain resilience is improved.

5.2 Stocktake analysis

While this stocktake found a broad range of actions and commitments across government and industry currently underway or planned to address natural and human induced risks in general, there are not many initiatives specific to the transport or supply chain context. Analysis also revealed further challenges that may impede efforts to increase resilience, and opportunities to address these gaps in the future to ensure road and rail supply chains remain resilient, including:

- Currently, organisations with a role in Australia's road and rail supply chains (such as state and territory transport and utility agencies) undertake their own vulnerability assessments and resilience planning processes. Stakeholders consulted as part of the Review indicated there are gaps in sharing findings, processes and lessons learned, leading to duplicated efforts and siloed management of risks. While there are existing data and information sharing platforms such as the National Freight Data Hub and Trusted Information Sharing Network for Critical Infrastructure Resiliencesource, stakeholders would welcome further opportunities to provide, improve and encourage the use of collaborative platforms across government and industry.
- There are benefits of longer-term investment as an approach to improving resilience (Brende & Sternfels 2022; NEMA 2022). While initial costs associated with prioritising and investing in resilience in new and existing infrastructure are higher, longer-term benefits include reduced costs and economic and social impacts in risk events (Deloitte 2021). Stakeholder consultation found consensus that supply chain networks and risks are continuously evolving, and ongoing future focused strategic planning is crucial to addressing these existing and emerging changes. While the National Urban Freight Planning Principles provide a useful resource, stakeholders would welcome further opportunities to collaborate, build on existing and develop longer-term approaches when considering freight network planning.
- Resilience is acknowledged in the current National Partnership on Land Transport Infrastructure Projects (NPA), an intergovernmental agreement governing Commonwealth funding for land transport infrastructure projects. The agreement stipulates that the Commonwealth recognise their collective transport investments enable broader outcomes that benefit Australians, including 'taking account of climate and disaster resilience and environmental sustainability in infrastructure planning and delivery' (Commonwealth of Australia 2019). The upcoming review of the NPA provides an opportunity to consider how funding principles and processes for the infrastructure investment programs and for maintenance can further contribute to resilient supply chains.
- Government and industry stakeholders consulted as part of the Review indicated that while the number and scope of existing resilience initiatives is impressive, the lack of a single, overarching national approach to address gaps and emerging issues in the transport context presents a risk to supply chain resilience. For example, currently, different states and territories focus on different essential commodities in times of emergency; jurisdictions use different approaches to measure risks such as flooding; and the geography and history of economic development means that different governments focus on different modes of transport. Additionally, concerns around data (including standards, sharing and interoperability) and challenges around lifting the capability and capacity of those responsible for managing and delivering infrastructure critical to supply chains are all potential barriers to achieving holistic resilience across the network.

6. Data

Improving the efficiency of targeted data generation, capture, sharing and use will better enable decision makers in government and industry to effectively and accurately assess, inform and improve road and rail supply chain resilience. Improved quality, accessibility and utilisation of supply chain data (e.g. real time freight movements, current disruptions and asset quality) can assist government and industry to:

- Better understand the way the freight ecosystem works and why operational decisions are made;
- Accurately measure and predict the impacts of risks to supply chains to develop informed policies, programs and strategies to address risks;
- Monitor, plan and prepare for current and emerging risks, and ensure quick and effective responses and resolutions to risk events as they occur; and
- Enable and improve transport and resilience outcomes.

6.1 Data gaps and requirements

The Review uncovered data gaps, consistency and accessibility issues that present a barrier for decision makers to better understand and be assured of the future resilience of Australia's road and rail supply chains. Improving data collection, standards, sharing, transparency and quality can enable a more functional and holistic understanding of the freight network (including intermodals and connecting infrastructure). Improving data as a tool will help to ensure the supply chain network is able to evolve and adapt to the changing environment and remain resilient.

High priority data needs to address current and emerging risks, respond to supply chain blockages, and build the resilience of road and rail supply chains, as identified by stakeholders consulted as part of the Review, include:

- **Data collection, consistency and sharing of:**
  - Up to date data on the asset quality of the road and rail network, including the status of rail and road infrastructure in regional and remote areas, and smaller freight and 'first/last mile' freight routes, to enable a more detailed understanding of key network vulnerabilities;
  - National freight data at a granular level (e.g. freight volumes, commodities, modes, vehicle types) to monitor the performance of supply chains and networks and respond to disruptions in a timely manner (e.g. recent or real-time data);
  - Road and rail network data, including nationally consistent data on current and historical freight movements and blockages, to provide greater visibility across the whole network; and
  - Natural hazard data, including flooding and bushfires, to ensure the consistency of underlying methods and assumptions when undertaking studies and in assessing risks across the country.
- **Research and analysis on:**
  - Key risks to road and rail freight, including future environmental scenario modelling and forecasts on the impacts of climate change;
  - The relationship between supply chains and risks, and the potential cascading consequences of multi-hazard events and flow on impacts across the network;
  - A set of essential commodities from a freight and supply chains system perspective, and potential route/transport alternatives and mitigation strategies if a disruption was to impact those commodities;
  - Strategically critical labour and capital inputs to the freight network, such as the required labour skills (current and future), and key fuels and materials (e.g. AdBlue additive);
  - Better understanding of road capacities, current conditions and regulatory barriers to heavy vehicle freight movement on the road and network, especially for decision makers at a local government level;
  - metrics and business processes to trigger emergency response and support; and
  - Quantifying resilience costs and benefits to better inform decision making and evaluation of business cases and project proposals.

The Review found that while some of this data may already be collected by the Commonwealth and industry, there is currently no single standardised format that data is collected and stored, and a lack of a common (or compatible/connected) operating platform to efficiently share this information. Stakeholder consultation highlighted this gap can diminish the effectiveness of responding in and preparing for times of crisis. The ability to share data efficiently is also limited by commercial in-confidence requirements, competition regulations and laws, and trust between entities to safely share and secure such data.

6.2 Current data initiatives and opportunities

While the Review recognises that there is still significant work to be done to address the data gaps and requirements mentioned above, there are a number of current initiatives across governments looking to resolve some of the identified gaps. Further development and promotion of the importance of better-quality data and data sharing to address resilience would be beneficial. This is part of the NFSCS long-term priorities.

National Freight Data Hub

The National Freight Data Hub (the Hub) will be a data sharing network that has an initial focus on Government providing better access to their data; facilitates data exchange, including by establishing data standards; and promotes leadership and innovation. By making high quality and timely freight data more widely available, the Hub will enhance the collection and access to freight data across all modes to:

- Improve strategic planning for infrastructure and transport network investment and other decisions;
- Improve the capture and sharing of freight data to support day to day operations; and
- Evaluate how the freight system is performing and what actions we can take to improve it.

A key project under the Hub is the National Location Registry, which will provide reliable and accurate location data across the freight industry. This includes precise locations of, for example, loading docks, opening hours, truck mass and dimension limits, a point of contact, safety requirements and further facility information. Industry can sign up to the *National Location Registry* now, and begin experiencing the benefits and adding data immediately.

Key Freight Routes Map Review and National Service Level Standards for Roads

The national KFR Map provides a detailed picture of the road and rail routes connecting Australia's nationally significant places for freight, including ports, airports and intermodal terminals, and is currently undergoing a review through the iMOVE CRC, to be delivered by December 2022. The review looks to conduct a SWOT analysis on the current KFR Map and identify any opportunities to improve its datasets and utility as a policy tool.

The review is also an opportunity to revisit how the KFR Map is used to inform investment decision making, particularly in the broader context of new National Service Level Standards for Roads (NSLS) that Infrastructure and Transport Ministers have commissioned. The NSLS will see a range of new information collected on the performance of all types of Australian roads, across the spectrum of service that customers care about (including road resilience). Benchmark standards will set the level of service that customers can expect, with an early focus on data on identified key freight routes, and this information will help road managers prioritise investments to areas most valued by customers.

TraNSIT

CSIRO's TraNSIT maps millions of vehicle trips across thousands of supply chains and as of July 2022, incorporates over 670,000 supply chain paths for 172 commodities between 540,000 enterprises. It comprises network modelling of over 28 million heavy vehicle, 15 million rail wagon, and 600 coastal shipping movements per year.

TraNSIT's capabilities include considering parameters such as costs, vehicle access and type, to analyse optimal supply chain routes between origins and destinations, and calculating cumulative impacts at various scales, to provide valuable information for infrastructure investment and regulatory decisions. TraNSIT also uses operating cost models for road and rail to estimate operation costs (including backloading). Costs of transport can be translated to dollars per payload tonne or total costs for individual supply chains.

The TraNSIT platform has been applied to analyse:

- Benefits of road upgrades such as sealing and access to higher productivity vehicles;
- Impacts of new or improved rail infrastructure at different locations, including new freight hubs;
- Impacts of disruptions to the road/rail network that create detours or freight unable to reach markets;
- Resilience of the road and rail network to climate or other disruptions;
- Impacts of future production or climate scenarios on freight volumes across the network, supply chain paths and bottlenecks that may occur;
- Impacts of regulatory changes such as driver fatigue, road or rail pricing and tolls; and
- Infrastructure investment options to maximise transport cost reductions.

CSIRO has developed two user-friendly web portals to analyse TraNSIT outputs:

- TraNSIT Web: currently available to Commonwealth agencies responsible for freight and logistics, allows various freight analysis along the transport network; and
- Supply Chain Benchmarking Dashboard: a publicly available tool that allows users to analyse and compare freight trends between commodities and across each leg of the supply chain. This tool was called for by industry and is part of the Commonwealth's efforts to focus on data and meeting future freight forecasts with specific reference to commodities.

7. Possible areas for further consideration

The Review's Terms of Reference includes scope to develop pragmatic options for government to mitigate or address risks to critical road and rail supply chains. This report (Phase 1), has identified a number of opportunities to improve systems and practices which could be considered as part of Phase 2 of the Review.

A national approach to resilience

The Review identified an opportunity to develop a national approach to elevate the importance of and address supply chain resilience, particularly before events occur. While there are many examples of government and industry responding effectively to blockages in the road and rail supply chain network as a result of various hazards (such as the role of the NCM and NHVR in times of disruption), there is currently no single avenue that focuses on supply chain resilience gaps and solutions to address issues. Similarly, while various existing initiatives focus on aspects of the freight network, there is no analysis or visibility of where common or unique issues may be nationally.

A large number of stakeholders highlighted the need for national leadership on risk and resilience policies, including current initiatives such as the NDRRF and associated National Action Plans, the National Climate Resilience and Adaptation Strategy, and the Critical Infrastructure Resilience Strategy.

Industry and government stakeholders expressed support for an overarching forum focused on supply chain resilience, which would be beneficial to encourage the collective conversation, coordination and action of strategic resilience priorities (such as critical routes, transport capabilities, essential commodities and emerging risks). This forum could also integrate resilience conversations around prioritisation, maintenance, and the roles of different levels of government when considering new projects seeking funding under major infrastructure investment programs.

While the Review adopts a high-level approach to assess the vulnerability of critical supply chains, it acknowledges that in reality, a disaster event may be more widespread and include greater complexities not captured in the Review's methodology. There are further opportunities to extend on the Review's resilience work, such as analysis and monitoring of existing network performance and capability; and scenario modelling of the impacts of evolving, complex and multi-hazard disruptions, to build a greater understanding of road and rail supply chain resilience.

Building resilience into infrastructure investment

The Review identified an opportunity for government and industry to develop a more holistic, longer term network approach when considering the design and planning of freight networks, and leverage off the significant investments to improve resilience (with a particular focus on vulnerable routes identified in this report). The upcoming review of the NPA, an intergovernmental agreement governing Commonwealth funding for land transport infrastructure projects, may allow consideration of how funding principles and processes for the infrastructure programs and maintenance can further contribute to resilient supply chains.

Further work could also include identifying where it is possible to facilitate the move from a just-in-time to a just-in-case mentality, to ensure supply chain disruptions can be managed in a proactive rather than reactive manner. Industry's just-in-time approach to freight is effective and efficient. However, this method can be limited in its capacity to provide contingency for sudden supply chain disruptions, resulting in resilience risks being borne by communities and the Commonwealth in times of crisis. Following recent disruptions, industry has been actively engaging in conversations around just-in-case approaches as part of its efforts to build resilience.

While the Review adopts a high-level approach to assess the vulnerability of critical supply chains, it acknowledges that in reality, a disaster event may be more widespread and include greater complexities not captured in the Review's methodology. There are further opportunities to extend on the Review's resilience work, such as analysis and monitoring of existing network performance and capability; and scenario modelling of the impacts of evolving, complex and multi-hazard disruptions, to build a greater understanding of road and rail supply chain resilience.

Data standards, collection and sharing

The Review found a need for better collection and sharing of data as a tool to address resilience issues, including establishing requirements for industry to provide and share data when they utilise public road and rail routes (such as national highways), and developing better collection and analysis of granular data nationally (such as asset quality, current and historical freight movements and natural hazard and climate change data).

Current Commonwealth data initiatives such as the National Freight Data Hub, the National Key Freight Routes Map and the National Location Registry were identified as tools that could be further explored as data mechanisms to share data, and support and inform resilience building of road and rail supply chains.

Capability and capacity

While out of the scope of the Review, stakeholder consultation found workforce issues remain prominent and present an ongoing risk to supply chain resilience. Issues such as a lack of skilled workers, retention and barriers to entry present a key risk to the effective operations of the freight sector, and accordingly, to resilience. Similarly, issues around capability and capacity gaps of those responsible for managing and delivering infrastructure critical to supply chains are also constraints.

Existing initiatives such as the National Transport Commission's National Rail Skills Hub and the Freight Industry Reference Panel's work on identifying transport workforce issues and opportunities will provide a greater understanding of workforce issues and ways to address them. The Department of Employment and Workplace Relations' Jobs and Skills Australia's data intelligence and analysis on the current, emerging and future state of the labour market, provides an opportunity to better understand the skills and training required in response to the evolving job description, rise of technology and digitisation of road and rail workers. Similarly, initiatives to enable better access to national and jurisdictional level resources, and understanding around heavy vehicle law and regulations could further address capability issues.

Additional mitigation strategies

While out of the scope of the Review, stakeholder consultation identified alternative transport methods and other mitigation strategies are important factors to consider when addressing the resilience of road and rail supply chains (e.g. the role of shipping and intermodals, and establishing higher stock levels of certain commodities in high risk areas). Consideration of these resilience building initiatives could be looked at through a broader risk strategy to address road and rail supply chain resilience. This could include opportunities for further consultation with key stakeholders (industry and government) on these issues.

8. Conclusion

The Review has identified and assessed the vulnerability of Australia's critical supply chain routes, the key risks that impact these routes, and existing initiatives that aim to lift resilience.

The Review has identified and analysed nine key risks that impact road and rail supply chains, with flooding posing the highest risks given its high likelihood and potential to disrupt supply chains across large geographic footprints. Flooding can impact many states and territories at one time, as demonstrated in the recent East-West rail corridor closure in January and February 2022. The key risks identified are not exhaustive, and there are a variety of other existing and emerging risks that are relevant to the supply chain context, including pandemics, shocks to the global supply chain, and workforce issues. As experienced in recent times, supply chain networks and their risks are changing, and will continue to do so. This means that governance, risk frameworks and actions to plan for and address risks will have to accommodate these changing risk profiles to ensure Australia's supply chain networks remain resilient.

The Review has identified critical key freight routes, and applied a risk framework to assess their vulnerability and identify the routes at highest risk. While some routes have been identified as critical due to large volumes of freight carried, a number of routes are critical in serving remote communities. While a majority of road and rail supply chain routes have been found to be generally resilient, with disruptions resulting in low detour costs and low impacts to communities, there are a number of vulnerable route segments and at intersections of strategic importance across the network. The Northern Territory is at highest risk of being adversely impacted by road and rail resilience factors, while the East-West rail corridor also has high vulnerability.

There are a range of existing initiatives across government and industry that are lifting resilience, including those that are actively monitoring current conditions of supply chains, raising awareness of future risks and preparedness to respond to future disruptions. Stakeholders consulted as part of the Review indicated that while the number and scope of targeted resilience initiatives is impressive, there are opportunities to develop an overarching national approach to address existing gaps and emerging issues in the transport context. A national approach would be beneficial to encourage the collective resilience conversation and coordination of action to ensure supply chain resilience is considered holistically across the network.

The Review found that while it is useful to identify essential commodities, the definition of essential is a complex and subjective undertaking. While definitions may vary, there are a number of existing frameworks to help identify commodities in times of crisis. Similarly, stakeholders consulted as part of the Review expressed the potential benefits of identifying the transport capabilities required to ensure commodities are able to be moved in times of disruption, including onto alternative routes and/or using alternative modes. The Review also heard that while existing governance and coordination arrangements have been effective in addressing recent disaster events and should continue, there are further opportunities to ensure Australia's road and rail supply chains remain resilient into the future.

The Review uncovered data gaps, consistency and accessibility issues that present a barrier for decision makers to better understand and be assured of the future resilience of Australia's supply chains. Stakeholder consultation highlighted that data is a useful tool in providing information, and improvements to data collection, standards, sharing, transparency and quality can enable a more functional and holistic understanding of the freight network.

Abbreviations

Short form	Long form
ACCC	Australian Competition and Consumer Commission
ACSC	Australian Cyber Security Centre
AEP	Average Exceedance Probability
ARTC	Australian Rail Track Corporation
BITRE	Bureau of Infrastructure and Transport Research Economics
BOM	Bureau of Meteorology
DFAT	Department of Foreign Affairs and Trade
DITRDCA	Department of Infrastructure, Transport, Regional Development, Communications and the Arts
FIRP	Freight Industry Reference Panel
IA	Infrastructure Australia
IPCC	Intergovernmental Panel on Climate Change
KFR	Key Freight Route
LGA	Local Government Area
NCM	National Coordination Mechanism
NEMA	National Emergency Management Agency
NDRRF	National Disaster Risk Reduction Framework
NFSCS	National Freight and Supply Chain Strategy
NHVR	National Heavy Vehicle Regulator
OSCR	Office of Supply Chain Resilience
TraNSIT	Transport Network Strategic Investment Tool

Glossary

Term	Definition
Acceptable risk	The level of risk that society is generally comfortable with.
Average Exceedance Probability	The probability, in percentage form, that an event will occur in a predefined future period.
AdBlue	An additive added to the exhaust of a diesel truck to stop it emitting harmful chemicals and excessive carbon dioxide.
Commodity	The Review has taken a broad approach to defining commodities to include raw material, goods (products derived from raw material) and services.
Commonwealth	In line with the Australian Government Style Manual, the Review refers to the Australian, state and territory governments collectively as the Commonwealth.
Consequence	The impact of a disaster event on an individual, group or community.
Disaster	A serious disruption of the functioning of a community or a society at any scale due to hazardous event(s) interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following losses and impacts: human, material, economic or environmental.
Disaster risk	The potential loss of life, injury, or assets that are destroyed or damaged which could occur to a system, society or a community in a disaster event.
Essential	The Review has taken a broad approach in considering a list of essential commodities to be used in assessing critical supply chain routes, and includes those that have the following characteristics: Principally for household consumption or immediately enters as an input for household consumption (e.g. food (unprocessed and processed) and water (components for the operations and maintenance continuity of water supply and sewage services)); • Fuel that is essential to maintain supply chains; and • Construction and transport material necessary to respond to broken supply chains.
Hazard	A source of potential harm or a situation with a potential to cause loss; a potential or existing condition that may cause harm to people or damage to property or the environment; an intrinsic capacity associated with an agent or process capable of causing harm.
Human induced hazard	Hazards which are the result of human intent, error, or as a result of failed systems. They can be caused by accidents in human built infrastructure or technologies, or intentional human actions that cause destruction, loss of life and/or damage and destruction of assets, including: • Cyber-attacks; and • Extremist Events.
Key Freight Routes (KFRs)	The road and rail routes connecting Australia's nationally significant places for freight, including ports, airports and intermodal terminals. The KFRs are identified through the collaboration of Commonwealth, state and territory governments and industry, to develop a more comprehensive understanding of Australia's freight system.
Likelihood	How often an event can be expected to occur.
Mitigation	Measures taken in advance of a disaster aimed at decreasing or eliminating its impact on society and environment.
Natural hazard	A natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. They include: • Bushfires; • Flooding; • Landslides; • Seismicity; • Cyclones and storms; • Extreme heat; and • Electricity disruption.
Recovery	The coordinated process of supporting emergency-affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical well-being.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.
Response	Actions taken in anticipation of, during, and immediately after an emergency to ensure that its effects are minimised, and that people affected are given immediate relief and support.
Risk	The likelihood of harmful consequences arising from the interaction of hazards, communities and the environment; the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood; a measure of harm, considering the consequences of an event and its likelihood.
Supply chain	The network of people, companies, products and services that gathers raw materials, transforms them into products and transports them to their final destination.

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Appendix A – Terms of Reference

All Australians depend on strong and resilient supply chains. The impacts of COVID-19, natural disasters and a growing freight task have shown the increasing importance of Australian on-land supply chains, and their critical importance to the national economy, and the lives and livelihoods of Australians. Understanding which supply chains are of national importance, the risks they face, and how government and industry can work to mitigate these risks is essential to ensure supply chains remain resilient and fit-for-purpose now and in the future.

In March 2022, the Hon. Barnaby Joyce MP, Deputy Prime Minister, Minister for Infrastructure, Transport and Regional Development commissioned a review into Australia's road and rail supply chain resilience. The Review will be led by the Bureau of Infrastructure and Transport Research Economics in the Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) supported by independent advice as required.

The Review will:

1. Define and determine key risks to critical supply routes – routes that transport large quantities of freight or are critical to supply of essential goods or services across Australia;
2. Identify key risks to critical supply routes in the short, medium and long term — including weather events or natural disasters, limited alternative routes, and limited and difficult to access alternative transport modes;
3. Assess the potential vulnerabilities in critical supply routes;
4. Complete a stocktake of recent relevant work by government and industry intended to identify and mitigate Australian domestic road and rail supply chain risks;
5. Identify data generation, capture and use requirements necessary to assess, inform best-practice and improve road and rail supply chain resilience;
6. Determine the critical routes at highest risk of failure; and
7. Develop and present pragmatic options for governments to mitigate or address risks to critical road and rail supply chains, in alignment with the Government-agreed framework to identify and mitigate critical supply chain risks.

The focus of the Review is on Australia's road and rail infrastructure and linked infrastructure. Matters such as international supply chain vulnerability, costs of freight, the transport workforce and critical inputs to the transport sector are outside the scope of the Review.

The Review will take into consideration supporting work, including but not limited to the:

- Australian Infrastructure Plan;
- National Freight and Supply Chain Strategy, including the National Freight Data Hub;
- National Urban Freight Planning Principles;
- Final Report of the Royal Commission into National Natural Disaster Arrangements;
- Final Report of the Productivity Commission Study into Vulnerable Supply Chains;
- National Rail Action Plan; and
- DITRDCA's Key Freight Routes Map.

The Review will engage closely with the Freight Industry Reference Panel, and also consult with:

- Key infrastructure owners and operators;
- Freight industry stakeholders – including freight customers;
- State and territory governments;
- Infrastructure Australia;
- CSIRO;
- The Department of the Prime Minister and Cabinet;
- The Department of Industry, Science and Resources (including the Office of Supply Chain Resilience);
- The Department of Home Affairs (including the Cyber and Infrastructure Security Centre and the National Emergency Management Agency);
- The Australian Climate Service;
- Any other groups DITRDCA deems necessary.

The Review will conclude and report to government by December 2022.

Appendix B – Resilience analysis of key freight roads and railways using CSIRO's TraNSIT

See supplementary materials.

Appendix C – Analysis of risks impacting the resilience of road and rail supply chains

See supplementary materials.

Appendix D – Stakeholder engagement

The Review has engaged with the following stakeholders:

Government		Other	
Australian Competition and Consumer Commission	Infrastructure Northern Territory	ARC Infrastructure	One Rail
ACT Government	National Heavy Vehicle Regulator	Australia Post	Pacific National
CSIRO	Jobs and Skills Australia	Aurizon	Ports Australia
Department of Climate Change, Energy, the Environment and Water (including the Australian Climate Service)	Ports New South Wales	Australasian Railway Association	QUBE Holdings
Department of Defence	Transport for New South Wales	Australian Centre for Rail Innovation	Roads Australia
Department of Finance	Victorian Department of Transport	Australian Livestock and Rural Transport Association	Ron Finemore Transport
Department of Home Affairs (including the Cyber and Infrastructure Security Centre and National Emergency Management Agency)	Department of the Premier and Cabinet (Western Australia)	Australian Logistics Council	SCT Logistics
Department of Industry, Science and Resources	Department of Transport (Western Australia)	Australian Rail Track Corporation	Truck Industry Council
Department of Infrastructure, Transport, Regional Development, Communications and the Arts	Main Roads Western Australia	Australian Trucking Association	Toll Group
Department of the Prime Minister and Cabinet	Public Transport Authority of Western Australia	Coles Group Limited	Water Corporation
Treasury	Water Corporation Western Australia	National Farmers Federation	Water Services Association of Australia
Freight Industry Reference Panel	Queensland Department of Transport and Main Roads	GrainGrowers Ltd	Woolworths Group
Freight Victoria	South Australian Department of Planning, Transport and Infrastructure	iMOVE	
Freight and Logistics Council of Western Australia	Tasmanian Department of State Growth	Linfox	
Infrastructure Australia	TasRail	National Transport Insurance	

Appendix E – Examples of best practice risk frameworks

Risk framework	Description
Australian Disaster Resilience Index	The Australian Disaster Resilience Index assesses the capacities for disaster resilience that emerge from structural settings. This index includes an interactive map that rates the strengths and weaknesses of each LGA for their ability to cope or adapt to a natural disaster. The ability to cope and adapt are defined by various social and economic indicators as well as indicators such as governance capabilities and access to information in a disaster. This framework reflects the importance of understanding how different communities are at different levels when it comes to the ability to cope and adapt to disasters.
EU Taxonomy Compass	The EU Taxonomy Compass is a visual representation of the contents of the EU Taxonomy – a list of economic activities by sector and how they need to change to become more sustainable, in accordance with relevant legislation. It allows a variety of users to understand how the economic activities they undertake may harm the environment and how they can meet criteria to make their activity sustainable. Relevant areas for this Review include the Transport Sector.
ISO 3100 – Risk Management	ISO 31000 – Risk Management is an internationally recognised set of general guidelines to consider when managing risk. The guidelines are a benchmark in risk framework development for various contexts and subject matter and provides organisations with the steps required to produce a thorough risk framework. Risk is defined in its most broad sense and is mostly just to guide decision makers in future.
Life Line Freight Routes	Austroads, the author of the paper, has created a risk indicator to help identify and determine priority roads, or 'Life Line' routes, for upgrade and maintenance on the basis of the value they present to the communities that they serve. Life Line freight routes are ones that are not necessarily carrying the most volume of freight but are critical to the communities that they serve. The Life Line Risk indicator tool helps road managers establish whether a route is a 'Life Line' route and which routes have the greatest claim for project funding.
National Disaster Risk Reduction Framework (NDRRF)	The NDRRF is a national framework designed to guide Australia's efforts to reduce disaster risk associated with natural hazards. It sets out four key priorities to reducing disaster risks: Understanding disaster risk; • Accountable decision making; • Enhanced investment; and • Governance, ownership and responsibility. The risk framework established as part of the Review applies the general guidance provided by the NDRRF to a road and rail supply chain specific context.
National Study of Infrastructure Risk	IA's risk reduction framework for infrastructure projects is part of IA's National Study of Infrastructure Risk. This framework assesses the likelihood of a range of natural and human induced risks to infrastructure projects by their likelihood and impact. Alongside the risk framework, IA has developed a risk repository to provide an indicative list of recent risks impacting on infrastructure projects. These include systemic, project related and sectoral risks that could impact infrastructure projects now and into the future.
Office of Supply Chain Resilience (OSCR)	The OSCR has developed an evidence-based approach to identify and address disruption risk in critical supply chains. This approach helps Commonwealth government agencies to assess the vulnerability, criticality, residual risk and targeted and proportionate responses of supply chains to ensure ongoing access to essential goods and services.
Profiling Australia's Vulnerability	Profiling Australia's Vulnerability provides insights into Australia's vulnerability to disasters and how these might grow and change into the future. The report explores Australia's coping capacity, what makes us vulnerable in a range of situations (such as access and supply of essential goods and services) and how risks may be addressed to lessen vulnerability into the future.

Appendix F – Summary of risks and impacts on critical KFRs

See supplementary materials.

Appendix G – Stocktake of current or recently completed resilience initiatives across government

See supplementary materials.

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