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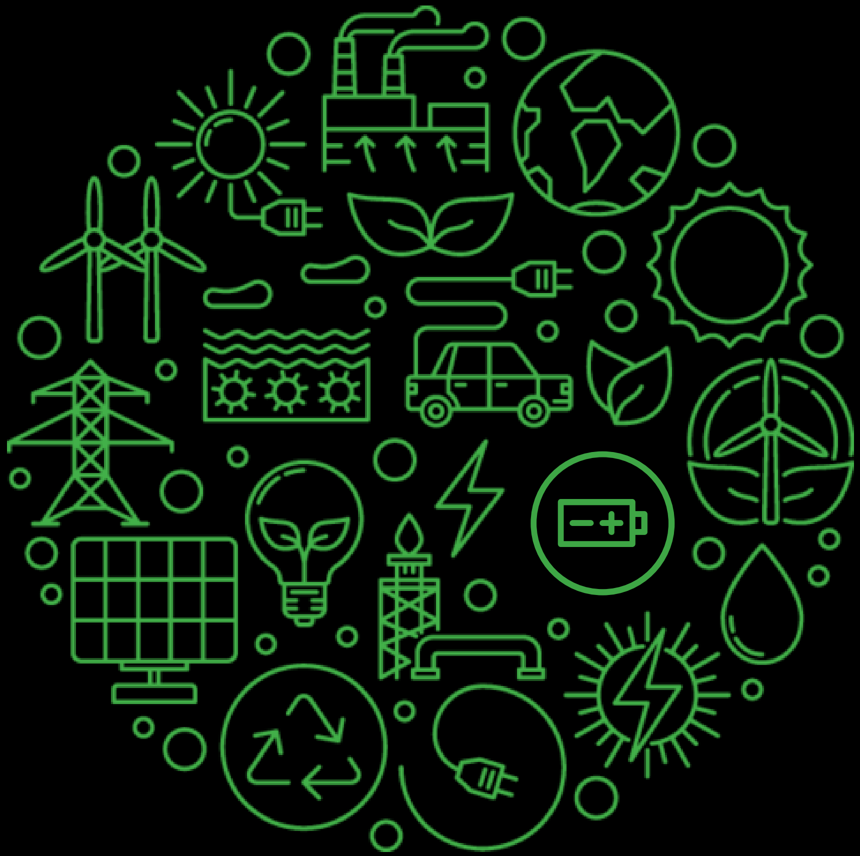


Bureau of Infrastructure and Transport Research Economics

Stocktake of risks and initiatives impacting resilience of road and rail supply chains

Final Report

Contents

Executive Summary

Resilient freight supply chains are key to Australia's economic prosperity. In recent years this has been underscored by compounding natural and human-induced shocks, including heavy rainfall and flooding to the east-west rail corridor, ongoing challenges of the COVID-19 pandemic, delays of critical supplies to rural and regional communities, and shortages of diesel exhaust additive AdBlue challenging fuel security.

In March 2022, the Minister for Infrastructure, Transport and Regional Development commissioned the Road and Rail Supply Chain Resilience Review ('the Review'). To inform the Review, this report undertakes a stocktake of natural and human-induced risks that may disrupt or damage road and rail infrastructure, as well as of government and industry initiatives recently completed, in place or in train that may contribute to the resilience of road and rail supply chains.

Approach

Government and industry initiatives were identified through desktop review, five informant interviews, and industry knowledge of the project team. The stocktake of risks was undertaken to align with the principles of ISO 31000 – Risk Management, resulting in preliminary prioritisation of the risks related to selected categories of natural and human-induced hazard using a likelihood and consequence framework. The risk assessment was informed by spatial analysis to identify the relative vulnerability road and rail segments nationally, taking into account potential for hazard exposure, sensitivity (i.e. tonnage of freight that could be impacted), and adaptive capacity (i.e. redundancy – presence/absence of alternative routes). Qualitative analysis was undertaken to report on non-spatial risks (e.g. cyber threats).

Please refer to page 8 for a summary of project limitations.

Findings

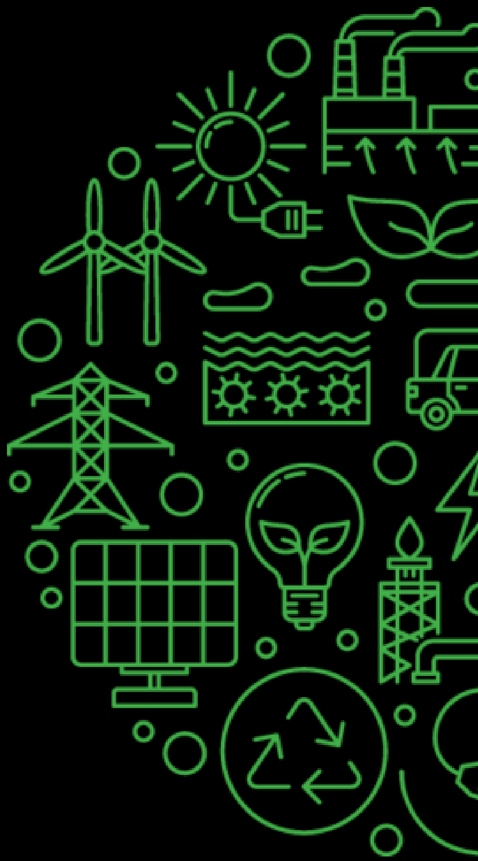
The Review identified a range of resilience-related initiatives varying from specific infrastructure investments that add redundancy to networks, through to capacity building programs for government employees around natural hazard and cyber risk management. Key gaps and challenges include duplicated efforts across jurisdictions, limited quantification of resilience costs and benefits in business cases, and balancing building back better with the imperative to quickly restore supply chain linkages following disasters.

Bushfires and flooding have been identified as the two natural hazards posing the most significant risks to Australia's road and rail supply chains. This reflects the potential for these events to cover a large geographic footprint, resulting in widespread disruptions and knock-on effects. Cyber attacks on transport-related operators' ICT systems were also identified as a risk to freight supply chains, with the attack surface for similar incidents increasing as more transport infrastructure components are controlled remotely.

Hazards included in the assessment

- Bushfire
- Flooding (combines flood, riverine flooding, and coastal inundation)
- Landslide
- Seismicity (combines earthquake and tsunami)
- Cyclones and storms (includes East Coast Lows)
- Extreme heat
- Electricity disruption
- Extremist event
- Cyber threats (includes issues such as ransomware, phishing and DDOS attacks)

Introduction



Road and Rail Supply Chain Resilience Review

In March 2022, the Minister for Infrastructure, Transport and Regional Development commissioned the Road and Rail Supply Chain Resilience Review ('the Review'). The Review is being led by the Bureau of Infrastructure and Transport Research Economics in the Department of Infrastructure, Transport, Regional Development and Communications (DITRDC). This report undertakes a stocktake of natural and human-induced risks that may disrupt or damage road and rail infrastructure, as well as work in progress that may be mitigating risks.

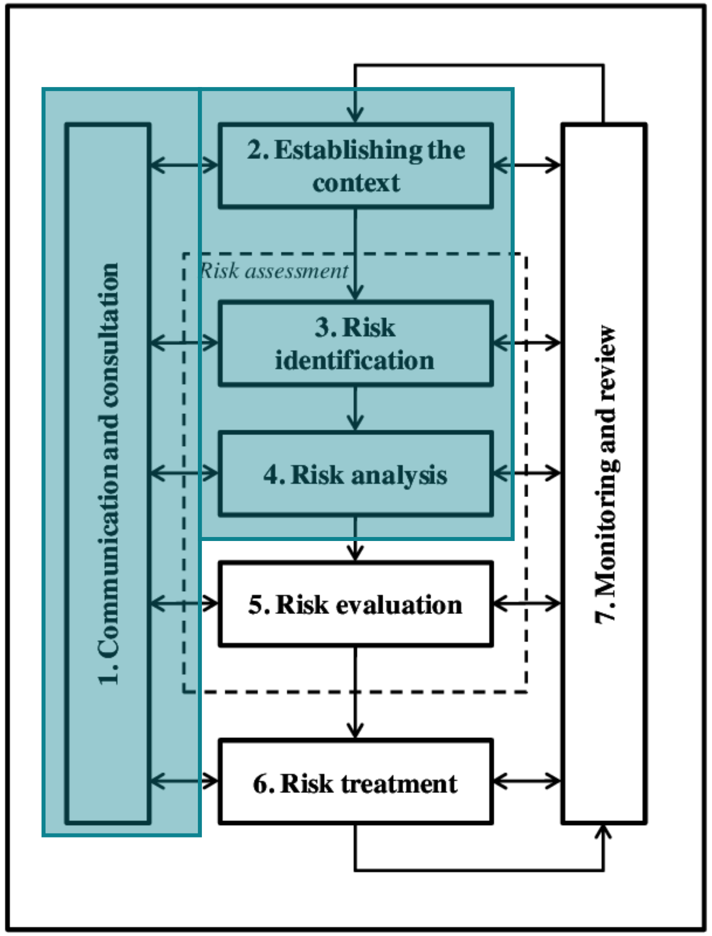
Objectives of the Review:

- Define and determine **key risks** to **critical supply routes**
- Identify key risks to critical supply routes in the **short, medium** and **long term**
- Assess potential **vulnerabilities** in critical supply routes
- Complete a stocktake of **recent relevant work** by government and industry to **identify** and **mitigate** road and rail supply chain risks
- Identify **data** generation, capture and use requirements to inform **best practice** and **improve resilience**
- Determine critical routes and **highest risk** of failure
- Develop **pragmatic options** for governments to **mitigate** or **address risks** to critical road and rail supply chains.

To support the broader Review, this report provides a stocktake of:

- Risks that impact on road and rail supply chains, including natural disasters and human-induced events
- Government and industry initiatives recently completed, underway or planned that may mitigate these risks.

The analytical approach aligns with steps 1-4 of ISO 31000 - Risk Management. It includes a review of the policy context and the range of hazards posing risks to Australian road and rail supply chains, identification of the risks to asset sub-classes (e.g. pavement, signalling), and preliminary prioritisation of the risks using a likelihood and consequence framework. This report does not draw conclusions about those risks that should be prioritised for further action or recommend risk treatment measures.



Steps in *ISO31000: Risk Management*

The resilience imperative for road and rail supply chains

Resilient freight supply chains are increasingly key to Australia's economic prosperity, with Australia's overall freight task projected to increase by 35% from 2018 to 2040.[1] In recent years this has been underscored by compounding natural and human-induced shocks including heavy rainfall and flooding to the east-west rail corridor, the ongoing challenges of the COVID-19 pandemic, delays of critical supplies to rural and regional communities, and shortages of diesel exhaust additive AdBlue challenging fuel security.

24 DAYS It took 24 days to repair the Trans-Australia Railway after **extensive flooding** in early 2022.

Examples of natural hazards

In January 2022, flooding initially impacted eight sites along 78km of the east-west rail corridor, with unusually high levels of rainfall further impacting rail freight infrastructure.[2] The tracks were closed for an intensive 24-day repair operation, requiring the reallocation of staff from other companies to assist recovery efforts.[3]

Major bushfires have also resulted in freight disruptions in recent years, particularly in south-eastern Australia, with closures to key routes affecting the flow of critical supplies.[4]

It is highly likely that climate change will exacerbate the frequency and intensity of natural hazards in the years to come, although these projected effects are outside this project's scope.[5]

56% Of global utilities companies reported at least one **cyber attack** in a 12 month period.

Examples of human-induced challenges

In 2020 and 2021, the COVID-19 pandemic created fundamental changes in Australia's freight task – for example, a 25% rise in consumer eCommerce deliveries increased the significance of urban freight and 'last mile' services.[6]

Pandemic-induced restrictions on movement within and between states and territories also resulted in significant delays, undermining the underlying assumptions of supply chains operating on a 'just in time' basis.

In December 2021, restrictions on Chinese exports of urea and concurrent price increases of natural gas (used to manufacture urea) resulted in a global shortage of diesel vehicle additive, AdBlue.[7] While local production has eased pressure on Australian fuel stocks, the shock has emphasised Australia's overreliance on a limited number of suppliers in many aspects of its supply chains.

Cyber attacks on critical infrastructure have increased significantly, with 56% of utilities companies globally reporting at least one attack involving an outage in operational technology in the 12 months between July 2020 and July 2021.[8] Increased integration between software and infrastructure expands the attack surface of critical infrastructure.

With the uptake of semi-autonomous vehicles and other intelligent transport systems (e.g. predictive maintenance solutions, variable speed limit signage, advanced train management systems), Australia's road and rail network is more vulnerable to disruption from cyber attacks than ever.

Policy context

The need to better understand risks to road and rail supply chains is underscored by a range of Commonwealth, state and territory policies. Undertaking the Review can support transport agencies to meet their obligations under strengthened critical infrastructure protection legislation, support identification of future infrastructure investments to build resilience, and encourage building back better when road and rail assets are affected by disasters. The list of policies discussed below is not exhaustive.

The **Australian Infrastructure Audit** acknowledges the diverse and growing nature of Australia's freight task. While Australia's mineral supply chains are world-leading, agricultural and urban supply chains are experiencing challenges. Agricultural supply chains suffer from poorly maintained local infrastructure and inconsistent interstate regulatory requirements. In addition, consumer freight in Australia is increasingly transported directly to homes and offices, creating bottlenecks in major cities.

The **Security of Critical Infrastructure Act 2018**, amended in 2022, introduces updated obligations on responsible entities to enhance national critical infrastructure (CI) management. In response to the increasingly interconnected and interdependent nature of Australia's CI, the updates include a legislated response to significant cyber incidents, cyber incident reporting obligations, expanding the definition of CI, and the requirement for CI operators to establish an 'all hazards' risk management program.

The **National Freight and Supply Chain Strategy** targets four key areas: 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. The Strategy is driven by an Action Plan, which identifies 13 actions, the first of which is to ensure that domestic and international supply chains are serviced by resilient and efficient key freight corridors, precincts and assets.

The **National Disaster Risk Reduction Framework** ('the Framework') is designed to guide Australia's efforts to reduce disaster risk associated with natural hazards. It acknowledges Australia's reliance on reliable transport networks (including road, rail, aviation and maritime), noting its complex interactions with other asset classes and functions such as telecommunications, energy, people and the environment. Key principles of the Framework include shared and defined responsibilities, as well as inclusive cross-sectoral engagement.

State Infrastructure Strategies (SIS) and Plans set strategic priorities for each state's infrastructure investment pipeline. Resilience is an increasingly prominent theme – for example, the NSW SIS 2018-2038 acknowledges the need to 'ensure NSW's 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'.

The Black Summer bushfires saw many affected communities cut off for a prolonged period, resulting in shortages of essential goods. In response, the **Royal Commission into National Natural Disaster Arrangements** recommended that 'Australian, state and territory governments, in consultation with local governments and the private sector, should review supply chain risks.' As a result, the **Office of Supply Chain Resilience (OSCR)** was established in 2021 and the $107m Supply Chain Resilience Initiative was announced in 2020 to position Australia to better respond to future supply chain disruptions.

The **Productivity Commission's Vulnerable Supply Chains report** in 2021 found that economic interdependencies expose supply chains to geopolitical, environmental, economic, societal and infrastructure-related shocks. Building off the Commission's work, the Australian Government has since established the OSCR to harness expert insight, monitor vulnerabilities in critical supply chains and coordinate whole-of-government responses. OSCR applies a Supply Chain Resilience Framework to identify risks, assesses industry's ability to manage identified risks, and determine when government action may be required.

Commonwealth assistance is provided to alleviate the financial burden of disaster events on states, territories and affected communities via the **Disaster Recovery Funding Arrangements 2018**. Beginning with QLD in 2013 following Severe Tropical Cyclone Oswald, disaster funding arrangements with the Commonwealth may also include a betterment component, allowing investments up to an agreed value that build back to a better standard than pre-disaster. Betterment provisions allow for investment in future risk reduction; however, their application depends on states and territories' willingness to engage in cost-sharing. Additionally, there is often competition between the imperatives to rapidly restore services and building back better.

Key limitations

This report and underlying analysis is subject to the following limitations, which should be considered when using it to inform decisions:

- The report relies almost exclusively on **publicly available data**. It is therefore subject to a range of gaps and inconsistencies – for example, flooding data has been compiled from studies completed by a range of state and local governments, with potential variations in underlying methods and assumptions, as well as large tracts of Australia where no data is available.
- The report does not comment on, or draw from data describing, the **condition and design parameters of rail and road assets**. While such data (e.g. pavement type and condition; annual exceedance potential (AEP) used in drainage designs) would contribute significantly to a more detailed understanding of key network vulnerabilities, it is typically held confidentially by third parties and could not be obtained within the time and resource constraints of this assessment.
- The assessment focuses on **heavy vehicle roads** and hence does not provide a clear picture of risks associated with 'final mile' freight movements on local roads.
- The report focuses on **acute hazards (also known as acute shocks)** that have the potential to physically damage, disrupt and/or degrade the level of service provided by road and rail supply chain infrastructure, including intermodal terminals. While critically important to the broader Review, upstream issues that may influence the flow of goods and services but do not physically impact infrastructure – such as geopolitical tensions, shipping delays, the COVID-19 pandemic, overreliance on a limited number of suppliers, and fuel shortages – are not the focus of this report. These broader issues are addressed by separate initiatives such as the Supply Chain Resilience Initiative, OSCR and the Productivity Commission's Vulnerable Supply Chains report.
- The hazards of bushfire, flooding, seismicity, landslide and cyclones/storms are treated equally in our spatial analysis. A weighting of 0.5 is provided to extreme heat exposure of roads, reflecting the comparatively minor consequences compared to hazards such as floods. Future iterations of this supply chain vulnerability analysis could **consider applying additional weightings** to reflect the relative significance of hazards.
- The prioritisation of risks is **qualitative and uses professional judgement** informed by a mixture of spatial analysis, desktop review of existing literature, and limited stakeholder engagement. No economic quantification of impacts has been undertaken.
- Sensitivity scores are based on tonnage moved across segments. **Tonnage is an imperfect proxy measure** to indicate how important a segment is to national road and rail supply chains, potentially skewing the results in favour of routes carrying bulk goods such as coal and grain.
- Prioritisation of risks is undertaken for the **current day only.** Underlying drivers of change in future risk such as climate change are not within the scope of this study, although qualitative commentary is provided in some cases about emerging risks, such as electricity supply and a potential future shift to battery electric trains and vehicles.
- Hazards and risks are **assessed and prioritised individually**. It is acknowledged that there are close relationships between some of the hazards considered in this study (e.g. extreme heat and bushfire; cyber attacks and electricity supply disruption), and that multi-hazard events and cascading consequences can occur. Some qualitative commentary is provided on these relationships and interdependencies.

Methodology overview

A high-level summary of the approach used in this study is provided below. A more detailed methodology can be found in Appendix 1.

1. Desktop review

A review of publicly available documentation was undertaken to define the policy context, explore existing natural hazard and disaster risk taxonomies, and understand typologies of road and rail asset classes and subclasses. Further, emergency risk assessments undertaken by each state and territory were reviewed to understand those natural and human-induced hazards that are considered to be priorities across Australia and are also relevant to freight infrastructure. This provided a basis for nine categories of hazard selected for more detailed analysis (see page 8).

2. Stakeholder interviews

Five semi-structured stakeholder interviews were conducted to add qualitative depth and validate the findings of the desktop review. The organisations consulted comprised a selection of peak bodies, a major logistics firm and the National Recovery and Resilience Agency. The interviews focused on the following themes: risk identification, risk prioritisation, navigating supply chain contingencies, existing supply chain initiatives, and relevant datasets. Broader and more in-depth engagement is being undertaken by BITRE as part of the broader review.

3. Spatial vulnerability analysis

Spatial analysis was undertaken to identify segments of Australia's land based supply chain with heightened vulnerability to disruption by priority natural hazards. Hazards identified in steps 1 and 2 were overlaid onto Australia's road and rail freight networks (using OpenStreetMap) to understand exposure (where and how assets and hazards intersect), sensitivity (segments carrying high volumes of freight – "Critical Route") and adaptive capacity (the availability of viable alternative routes to a potentially-impacted segment). See the next page for further detail.

4. Risk identification and prioritisation

Following analysis of exposure, sensitivity and adaptive capacity, risks were prioritised at the national scale. Prioritisation is defined thorough analysis of likelihood of an infrastructure component (e.g. pavement, Intelligent Transport Systems) being impacted by a hazard, and the seriousness of the consequence to the supply chain under a reasonable worst case scenario. For natural hazards the rating drew on the outcomes of steps 1, 2 and 3; for human-induced hazards no spatial analysis was undertaken. Confidence ratings were applied for each risk to indicate the extent to which risk and its associated rating is supported by evidence.

The full list of risks is catalogued in Appendix 1.

Prioritising key hazards

A three-step process was undertaken to prioritise key hazards facing road and rail supply chains. An initial list of 29 hazards appearing in Australia's state and territory level emergency risk assessments was filtered down to 21 with the potential to damage, disrupt or degrade road and rail assets. The filtered hazards were then further prioritised by relevance to state and territory assessments, with those appearing in the majority of these assessments retained, as well as regionally-specific hazards with potentially catastrophic consequences (e.g. cyclones in northern Australia). Hazards such as 'pandemic influenza', 'infrastructure failure', 'road crash' and 'rail crash' were also discarded as they do not reflect underlying drivers of damage to road and rail infrastructure. However, it is noted that road and rail crashes can indeed cause freight disruptions, as seen in the 2007 Burnley Tunnel crash.

All Hazards

Hazards identified across all Australia's state and territory level emergency risk assessments and Royal Commission into Natural Disaster Arrangements.

- Bushfire
- Flood
- Landslide
- Earthquake
- Cyclones
- Extreme heat
- Electricity disruption
- Terrorism
- Cyber attack
- Storm
- Water or Sewerage Emergency
- Hazardous materials incident (chemical substances)
- Tsunami
- East Coast Low
- Infrastructure Failure (communication, dam flood, transport)
- Road Crash
- Rail Crash
- Coastal Erosion
- Air crash
- Riverine Flooding
- Coastal Inundation
- Maritime emergency
- Pandemic influenza
- Water supply disruption
- Biosecurity (includes exotic/endemic animal, plant and pest emergencies)
- Emergency animal disease
- Emergency plant pest
- Gas supply disruption
- Mine emergency

Filtered Hazards

Remaining hazards filtered based on by their potential to damage, disrupt or degrade road and rail infrastructure.

- Bushfire
- Flood
- Landslide
- Earthquake
- Cyclones
- Extreme heat
- Electricity disruption
- Terrorism
- Cyber attack
- Storm
- Water or Sewerage Emergency
- Hazardous materials incident (chemical substances)
- Tsunami
- East Coast Low
- Infrastructure Failure (Communication, dam flood, transport)
- Road Crash
- Rail Crash
- Coastal Erosion
- Air crash
- Riverine Flooding
- Coastal Inundation

Final Hazards

- **Bushfire**
- **Flooding (combines flood, riverine flooding, and coastal inundation)**
- **Landslide**
- **Seismicity (combines earthquake and tsunami)**
- **Cyclones and storms (includes East Coast Lows)**
- **Extreme heat**
- **Electricity disruption**
- **Extremist event (reframing of 'terrorism')**
- **Cyber threats (reframing of 'cyber attack' – includes issues such as ransomware, phishing and DDOS attacks)**

Spatial analysis approach

To better understand the most vulnerable segments of road and rail supply chains, spatial analysis focuses on the following factors: exposure, sensitivity and adaptive capacity. The product of these factors is the vulnerability score for each hazard and overall vulnerability score. These are available by network segment, Statistical Area (SA) 3 and SA4.

VULNERABILITY FACTORS

Exposure – *which segments are in locations that could be impacted by priority hazards?#*

Proximity between hazard extents and road or rail segment is calculated. Based on a distance threshold, proximity is classified as either low, medium or high.

Sensitivity – *which segments carry significant volumes of freight that could be disrupted?*

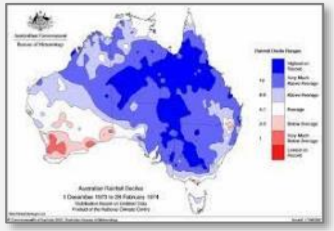
Road and rail origin and destination data is combined with SA3 location data to inform key freight routes by tonnage transported. Sensitivity is ranked by the amount carried over each segment of the network. Broadly analogous to the concept of 'criticality'.

Adaptive capacity – *do viable alternatives existing if a road segment is disrupted?*

Road networks from SA3 data is checked for alternative paths for each route. Adaptive capacity is calculated based on the number of alternative paths.*+ Analogous to the concept of 'redundancy'.

CONCEPTUAL ANALYTICS PROCESS

Spatial Hazard Data



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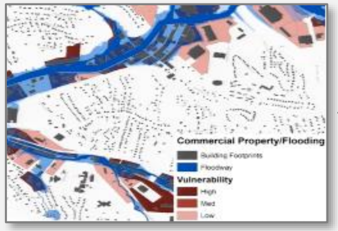
Road and Rail Networks

Exposure
Asset & Hazard Intersection



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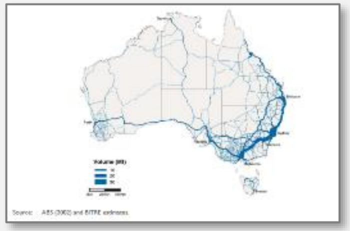
Sensitivity
Freight Volumes



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Adaptive Capacity
Road corridors with limited alternatives if disrupted

OUTPUTS

Interactive maps of road and rail networks in Tableau Dashboard

Aggregated National risk ratings

Likelihood \ Consequences	Low	Med	High
High	M 227	H 0	H 181
Med	L 45	M 0	H 0
Low	L 105	L 35	M 7

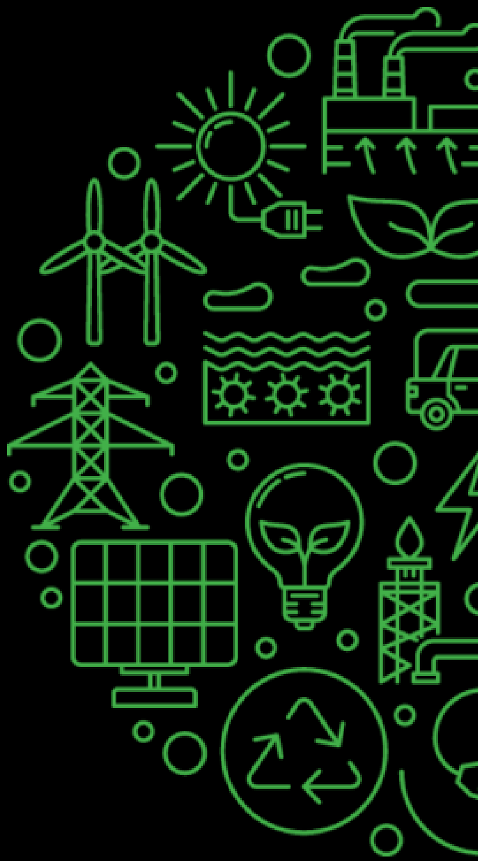
** This has not been undertaken for rail as factors such as timetabling can fundamentally affect the capacity to re-route, even where an alternative route exists.*

+ The adaptive capacity assessment makes the simple assumption that only a single segment would be cut off if exposed to a hazard event. This underestimates the potential impact of an event with a wide footprint, such as major flooding across a large floodplain, which could affect many routes simultaneously.

 # Refer to page 44 and 45 for datasets used to determine exposure scores.

Note: The methodology above describes Deloitte's vulnerability analysis. To avoid confusion, BITRE's Road and Rail Supply Chain Resilience Review does not use Deloitte's references to sensitivity and adaptive capacity, as described in this report. The Review uses a different methodology and inputs for sensitivity and adaptive capacity (using CSIRO's TraNSIT) to undertake its vulnerability analysis.

Findings



Existing initiatives

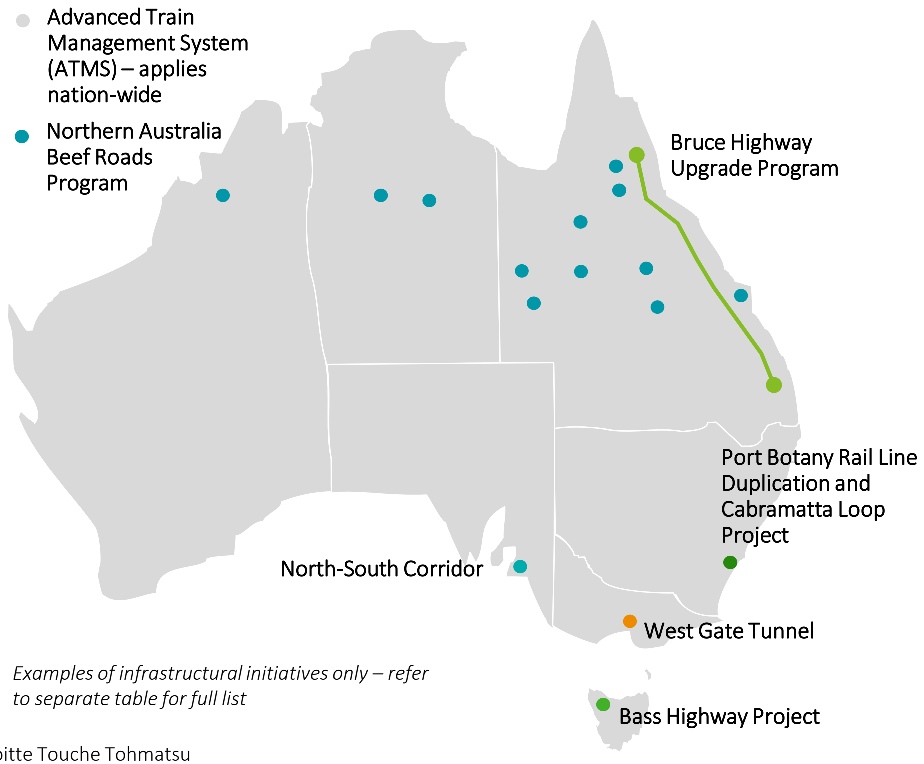
This study has undertaken a stocktake of government and industry initiatives recently completed, currently in place or yet-to-be-implemented that may contribute to the resilience of road and rail supply chains. As extensive stakeholder engagement was not part of the project scope this stocktake is by no means exhaustive.

This section provides examples of relevant actions under a typology adapted from the categories used in Infrastructure Australia's (IA) *A Pathway for Infrastructure Resilience* to describe opportunities for systemic change in infrastructure planning.[9] A table with details of all initiatives identified has been provided to BITRE separately.

New infrastructure & infrastructure renewal/improvement

The planned or ongoing construction of new road, rail, and enabling infrastructure (e.g. telecommunications) projects, and

Upgrades to existing road, rail and enabling infrastructure intended to improve resilience, safety, accessibility and/or reliability



Examples of infrastructural initiatives only – refer to separate table for full list

Example Initiatives

Governance and coordination

Initiatives and agencies seeking to foster the enabling environment to better anticipate, manage and adapt to natural and human-induced hazards. This includes collaborative forums, sectoral strategies and information sharing arrangements.

- Australian Government Crisis Management Framework (AGCMF) and National Coordination Mechanism
- AUSTROADS Environment and Sustainability Taskforce
- National Rail Action Plan
- State Infrastructure Strategies
- National Freight & Supply Chain Strategy
- Australia's Cyber Security Strategy 2020
- National Climate Resilience and Adaptation Strategy 2021-2025

Data and insights

Typically research and development initiatives that assist in understanding the current and future supply chain resilience landscape by assessing risks, developing resilience options, and improving data quality/availability.

- Electricity Sector Climate Information (ESCI) Australian Climate Service
- National Freight Data Hub
- CSIRO TraNSIT model
- iMove Cooperative Research Centre (CRC)
- Natural Hazards Research Australia portfolio
- National Asset Centre of Excellence (NACoE)

Capacity building

Initiatives aimed at building the knowledge, expertise and ability of freight stakeholders (e.g. senior leaders, workforce) to support the resilience of networks to natural and human-induced hazards

- Australian Cyber Security Centre's Essential 8 strategies
- NSW Climate Risk Ready Guidelines
- Rail Industry Worker Program

Existing initiatives – gaps and challenges

This study identified a range of resilience-related initiatives varying from specific infrastructure investments that build more diversity into freight networks (e.g. West Gate Tunnel providing an alternative Yarra River crossing in Melbourne), through to capacity building programs for government employees around natural hazard and climate risk management (e.g. NSW Climate Risk Ready). As summarised below, the stocktake of initiatives reveals some key challenges for increasing the resilience of road and rail supply chain infrastructure, including duplication of effort and competing imperatives.

Organisations with a role in Australia's road and rail supply chains (e.g. state/territory transport agencies; utilities) each undertake their own vulnerability assessments and resilience planning processes. It was suggested through some stakeholder interviews that – despite the existence of mechanisms such as the Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience – many organisations are unwilling to share the outputs of such assessments. This can lead to duplicated effort and siloed management of risks.

The National Partnership on Land Transport Infrastructure Projects acknowledges the need for investments to take account of "climate and disaster resilience and environmental sustainability in infrastructure planning and delivery". However, the funding principles of underlying initiatives such as the $5.8 billion Roads of Strategic Importance (ROSI) package do not specifically cite building resilience or integrating such principles into projects. Outcomes may be improved by more specific requirements around how resilience considerations should be integrated into projects seeking funding under major infrastructure investment programs.

Through publications and initiatives such as IA and Infrastructure NSW's (INSW) *A Pathway to Infrastructure Resilience* and the CSIRO's Enabling Resilience Investment Framework (ERI), there is increasing acknowledgement of the need to better value the costs and benefits of proactive resilience investments in business case processes. While measures such as real options analysis have been piloted and are increasingly encouraged, conventional approaches to benefit-cost analysis (BCA) remain the norm across states and territories. The IA/INSW paper also advocates for a shift in focus from the resilience of assets themselves, to the contribution of assets to the resilience of end users and systems.

The Australian Climate Service (ACS) has been established in response to a recommendation in the *Royal Commission into National Natural Disaster Arrangements*, with the aim of bringing the Commonwealth's extensive climate and natural hazard information into a single national view. However, this is unlikely to provide a near-term solution to the issue of inconsistent collection and management of data on flood risk by state and local governments, which have ultimate responsibility for managing these issues through land use planning.

While the historic approach to disaster recovery funding has been to support only restoration of infrastructure to pre-disaster conditions, the recent trend towards establishment of betterment funds is a positive development for road and rail resilience. However, primacy is often given to rapidly restoring freight movement when highly critical supply chain routes are disrupted, rather than the potentially lengthier closure required to build back better. This was reported to be the case following flooding of the Trans-Australia railway.

Betterment is at the discretion of state and territory jurisdictions and there are limited levers available to the Commonwealth under current arrangements to influence how they choose to rebuild critical infrastructure.

State transport agencies have increased their requirements for infrastructure resilience through adoption of the Infrastructure Sustainability (IS) rating scheme for large capital projects. The threshold at which such assessments are required varies (e.g. CAPEX > $50m in NSW and >$100m in QLD).

The IS tool encourages completion of a climate change adaptation plan and all hazards resilience assessment. These assessments can result in meaningful changes to project design and operational specifications (e.g. increased levels of flood immunity). However, the process is usually undertaken during concept or detailed design; many pertinent decisions regarding hazard vulnerability (e.g. selection of the route alignment; funding assignment for resilience measures) are undertaken earlier in the investment lifecycle.

Understanding how hazards can impact road and rail assets

Through the desktop review, it was identified that organisations in the transport sector use varying typologies to describe the components of road and rail infrastructure. The matrix below uses a simple asset typology reflecting components of road and rail network that could be impacted – either directly or indirectly – by the nine hazards under assessment. Conclusions about the potential for impact are based on existing studies into road and rail infrastructure resilience and professional opinion. This process informed the identification of risk statements.

It should be noted that electricity disruption can be a direct cause of impacts on transport networks (e.g. 2021 Callide Power Station explosion); however, other natural (e.g. Black Saturday bushfires affecting key power transmission lines; downed powerlines during cyclones) and human-induced hazards (e.g. cyber attacks targeting power infrastructure) could also be the underlying cause for electricity disruptions.

	Common to Road and Rail					Road Components			Rail Components			Intermodal terminals	
Hazard	Bridges	Tunnels	Retaining walls	Electricity substations	Drainage	Pavement - asphalt	Pavement - concrete	Signalling, notifications & Intelligent Transport Systems	Rail, sleepers and fasteners	Signalling equipment & overhead wires	Rolling stock	Cranes and lifts	Storage, yards & warehousing
Flooding	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Indirect	Direct	Indirect	Direct	Direct	Direct
Bushfire	Direct	Indirect	Direct	Direct	Indirect	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Landslide	Direct	Direct	Direct	Direct	Indirect	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Seismicity	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Indirect	Direct	Direct
Cyclones	Direct	Indirect	Direct	Direct	Indirect	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Extreme heat	Negligible	Negligible	Direct	Direct	Negligible	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Indirect
Cyber threats	Indirect	Direct	Negligible	Direct	Indirect	Negligible	Negligible	Direct	Negligible	Direct	Direct	Negligible	Indirect
Electricity disruption	Indirect	Direct	Negligible	Direct	Indirect	Negligible	Negligible	Direct	Negligible	Direct	Indirect	Direct	Direct
Extremist event	Direct	Direct	Direct	Direct	Direct	Negligible	Negligible	Direct	Negligible	Direct	Direct	Direct	Direct

Rating	Description
Direct	Hazard can directly impact the infrastructure component (e.g. flood washing our rail ballast)
Indirect	Hazard impacts elsewhere can have flow-on effects to the component (flooded substation causing power outage, resulting in signalling failure)
Negligible	No or little effect of proposed hazard on infrastructure component

High rated risks to road and rail supply chains

Bushfires and flooding have been identified as the two natural hazards posing the most significant risks to Australia's road and rail supply chains. This reflects the potential for these events to cover an extremely large geographic footprint, resulting in widespread disruptions with knock-on effects across multiple states and territories. Major supply chain disruptions can also occur without actual damage to road and rail infrastructure from bushfires, as the significant safety risks posed by such events can lead to precautionary closures.

Cyber attacks on transport-related operators' ICT systems were also identified as a risk to freight supply chains with potentially widespread consequences. This was observed through the phishing and ransomware attacks on a major logistics company's systems, with the attack surface for similar incidents increasing as more transport infrastructure is controlled remotely (e.g. connected vehicles; ARTC Advanced Train Management System).

Risk Statement	Consequence	Likelihood	Overall Risk Rating	Confidence Rating
Flooding causing temporary inundation and closure of rail corridor, resulting in delays and disruptions to freight flows	High	High	High	High
Bushfires in proximity to road freight routes resulting in temporary closure	Medium	High	High	High
Bushfire smoke resulting in decreased visibility, leading to road speed restrictions and heightened safety risks	Medium	High	High	High
Flooding causing temporary inundation and closure of roads, resulting in delays and disruptions to freight flows	Medium	High	High	High
Bushfire proximate to freight rail reserves, resulting in temporary total closure of corridor	Medium	High	High	High
Bushfire causing damage to rail infrastructure (e.g. signalling, sleepers, debris over track) requiring specialised repair before freight services can recommence	High	Medium	High	High
Malicious cyber activities (e.g. phishing, ransomware, DDOS attacks) directed at freight operator and/or train control systems, potentially resulting in delays and safety risks	High	Medium	High	Medium

The following pages of this report summarise the risks identified for each category of hazard. For simplicity, maps in these sections include selected major roads and railways only – mapping in the separate Tableau dashboard includes wider road and rail networks.

Rating Guidance

Each risk statement has been assessed based on current day likelihood, multiplied by the consequence of a reasonable worst case scenario event.

Rating	Consequence
Low (1)	Impacts largely confined to a discrete region with duration less than two days
Medium (2)	Impacts widespread (geographically or population) for up to one week; or Impacts localised but disruption extends longer than one week
High (3)	Impacts widespread (geographically or population) and it could take over one week to restore freight flows

Rating	Likelihood
Low (1)	May occur once in a lifetime
Medium (2)	Occurs a few times a generation
High (3)	Occurs at least once per year

	Low	Medium	High
Low	1	2	3
Medium	2	4	9
High	3	6	9

** Refer to Appendix 1 for further information on the approach, including confidence rating guidance*

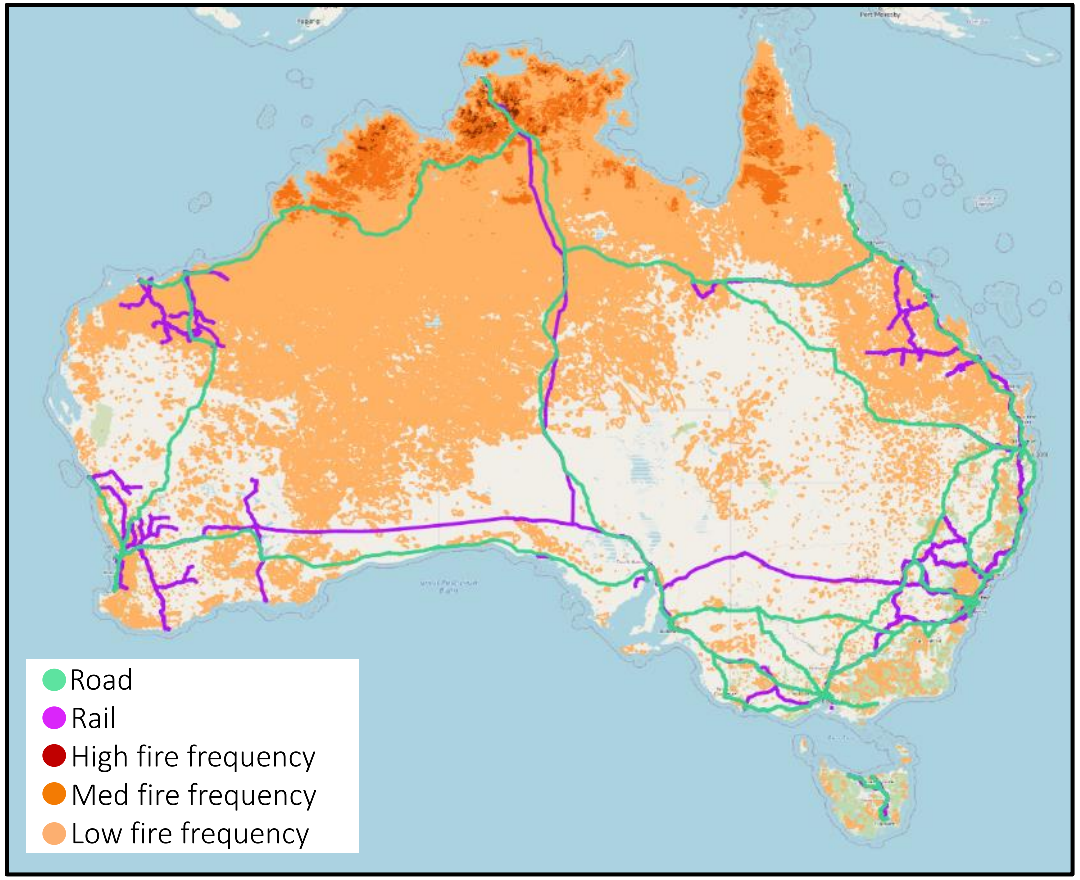
Risk summary – bushfire

During the 2019-2020 bushfire season, the economic cost of was estimated at over $2.1 billion in Victoria alone, with fires causing major structural damage to road and rail infrastructure components across Australia.[10] As a result of the same fires in NSW, the Blue Mountains Line – which is crucial for haulage of coal to coastal ports – was closed to freight services for one month, with services limited for several months more as repairs took place to allow recommencement of passenger services.[11]

Bushfires proximate to key corridors can result in preventative closures due to risk of direct fire impact and/or reduced visibility from windblown smoke. Given the potential for bushfires to cover widespread areas, this can result in knock-on effects nationally. While not directly within the scope of this study, it is difficult to separate bushfire risk from the issue of climate change, with Intergovernmental Panel on Climate Change stating with high confidence that the intensity, frequency and duration of fire weather events is projected to increase throughout Australia.[12]

Risk	Risk Rating	Confidence Rating
Structural damage to bridges, resulting in closures and repair costs	Med	High
Bushfires in proximity to road freight routes resulting in temporary closure	High	High
Bushfire smoke resulting in decreased visibility, leading to road speed restrictions and heightened safety risks	High	High
Fire in tunnel or near access/egress resulting in temporary closure	Med	High
Melting, cracking and/or deformation of asphalt pavement	Med	High
Damage to signalling and Intelligent Transport Systems (ITS), resulting in delays and disruptions to freight flows	Low	High
Damage to electrical substation, disrupting power supply to signalling and ITS	Med	Med
Severe bushfire danger conditions resulting in speed restrictions and associated freight delays	Med	High
Bushfire proximate to freight rail reserves, resulting in total closure of corridor for up to a month	High	High
Damage to rail infrastructure (e.g. signalling, sleepers, debris over track) requiring specialised repair before freight services can recommence	High	High
Damage to intermodal terminal facilities, resulting partial or full closure	Med	Low

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*



Risk summary – flood

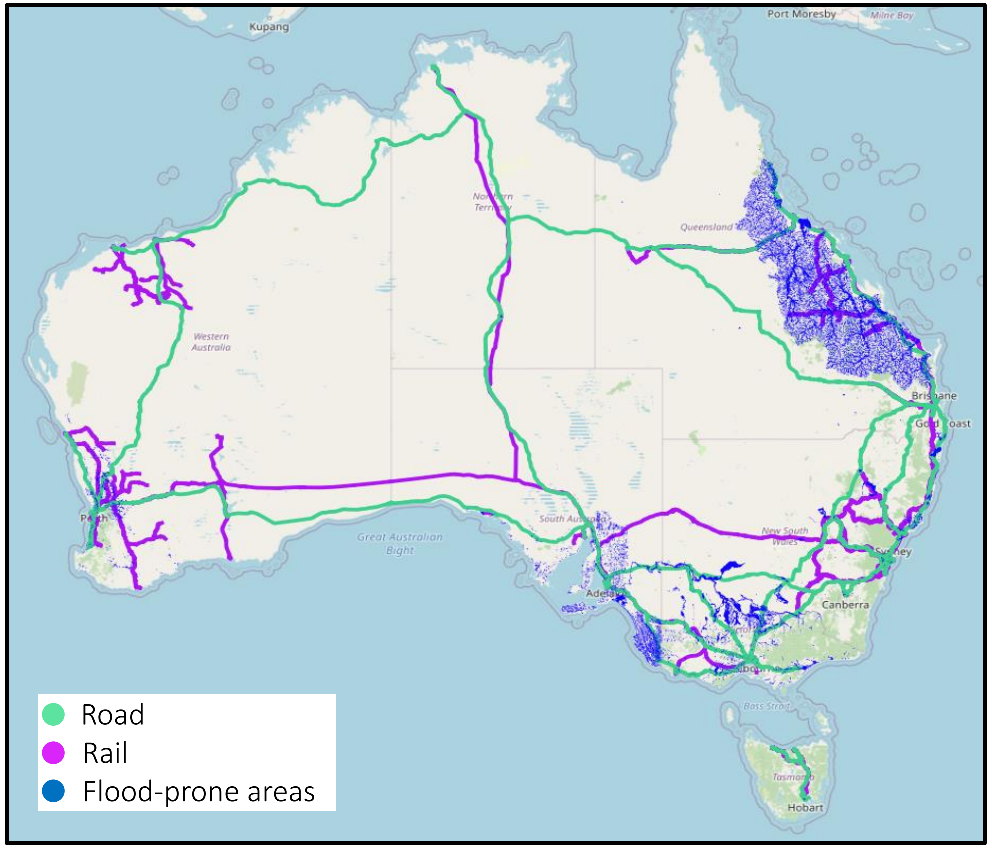
Flooding is a high-profile natural hazard that has caused significant damage and disruption to road and rail supply chains over recent years. Ballasted track and unsealed roads are more sensitive to damage and disruption from floods than sealed roads, although the latter can also be damaged by floodwaters.

The most disruptive recent events have been due to riverine flooding (which has also been the focus of spatial analysis in this project). Mapping below shows the significant extent of land prone to riverine flooding under a 1% AEP event – note that much of Australia is not covered by flood studies, which tend to centre around major urban areas. While not mapped below, the potential for coastal inundation of supply chain assets should also be acknowledged – this is particularly relevant for low-lying road and rail routes into ports carrying significant volumes of freight.

While the focus of this study is on current day risks, it must be noted that climate change is projected to result in more intense downpours and sea level rise. This is likely to influence the future frequency and severity of riverine, coastal and rainfall flooding, meaning an historic 1% AEP event would have a greater chance of occurring in a given year.

Risk	Risk Rating	Confidence Rating
Water ingress to tunnels overwhelms drainage systems, leading to flooding and temporary closures	Med	High
Flooding contributes to rising groundwater table, resulting in faster erosion of side slopes and increased risk of slope failure	Low	Low
Floodwaters contributing to saturation, salination and/or increased moisture of pavement foundation, resulting in damage	Med	High
Flooding causing temporary inundation and closure of roads, resulting in delays and disruptions to freight flows	High	High
Coastal inundation contributing to corrosion of concrete pavement and/or structures	Low	Low
Inundation of electrical substation, disrupting power supply to signalling and ITS	Low	Med
Flooding causing temporary inundation and closure of rail corridor, resulting in delays and disruptions to freight flows	High	High
High velocity flooding causing significant ballast wash-out, resoling in closure of corridor unless passing loop available	Med	High
Increased soil moisture results in 'mud pumping' (soil fluidisation beneath ballast). This can cause in track instability resulting in speed restrictions or full track closure in extreme cases.	Med	Med
Flooding of intermodal terminal facilities, resulting in delays loading/unloading freight	Med	Low
Biodegradation of ageing timber bridge structures, resulting in unsafe conditions and closures	Low	High

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*



Risk summary – landslide

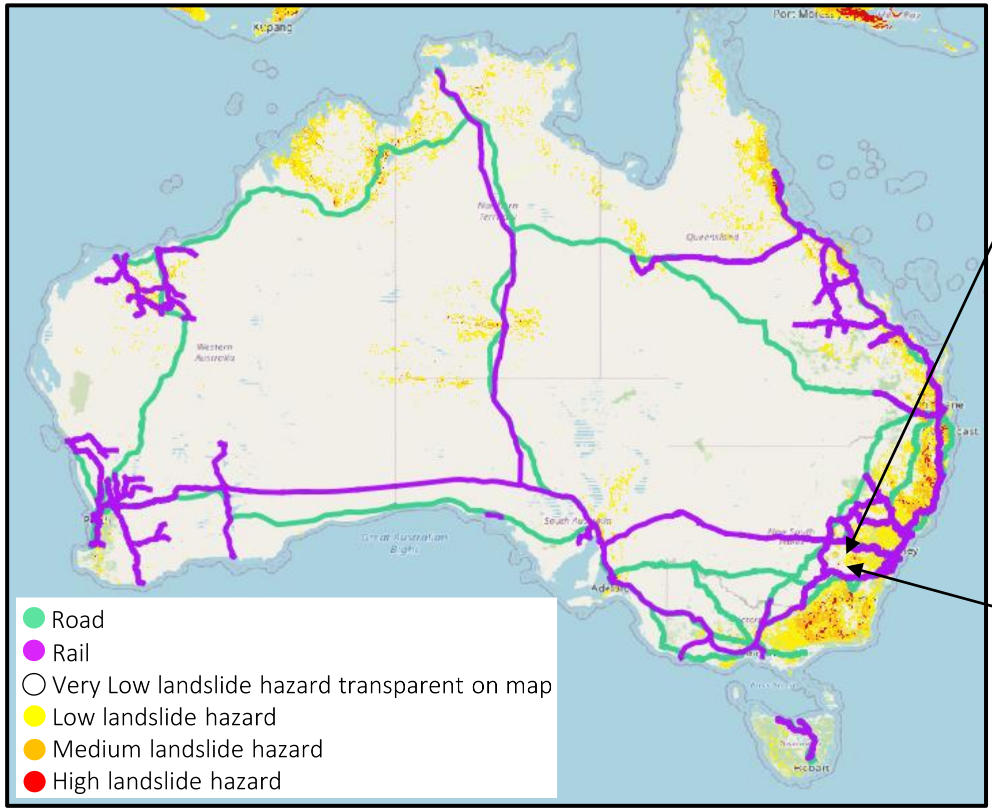
Landslides often occur as a result of other natural hazards such as heavy rainfall and earthquakes, but can also occur as a result of human activity including the removal of vegetation, modification of drainage, construction of roads, and vibration from heavy traffic.[13] [14] Erosion from floodwaters can trigger further displacement of soil and vegetation, causing further landslides.

In March 2022, floods from heavy rain caused landslides, cutting off road access and power to Kangaroo Valley in South Coast NSW. Landslides are also a common occurrence in the Blue Mountains, with timber supply chain routes affected by a series of events over recent years near Oberon and Jenolan Caves.

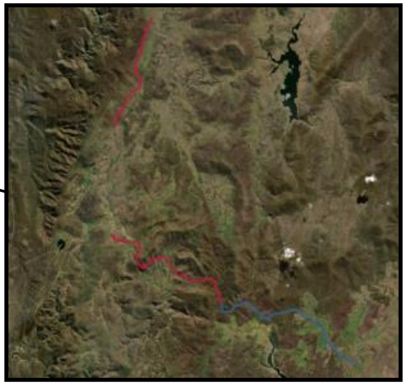
Landslides can occur suddenly, damaging roads, railways, and ancillary infrastructure supporting road and rail supply chains.[15] As landslide-prone areas are less widespread than most other hazards considered in this study, the potential impacts on supply chains are likely to be more localised. However, the Australia Geomechanics Society notes that there is an increased likelihood for damage to property from landslides due to development in prone areas.[16]

Risk	Risk Rating	Confidence Rating
Natural landslide debris can cause road retaining walls to suffer cracking from movement of earth and sub-grade soil	Low	Medium
Landslide debris partially or completely blocking road, resulting in closure	Med	Medium
Landslide causing rail tracks and components to be submerged under debris, potentially resulting in potential prolonged closure	Med	Medium

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*



Long Plain Road, NSW



Snowy Mountains Highway, NSW

Note this map uses the Global Landslide Hazard Map allow for consistent analysis at a national scale, as opposed to combining different local assessments with different methods. However, this is likely to result in underestimation of the number and extent of supply chain linkages potentially affected by this hazard.

Risk summary – seismicity

According to Geosciences Australia, 100 earthquakes of magnitude three or higher are recorded on average in Australia each year.[17] While damaging incidents are extremely rare, state emergency risk assessments nonetheless address earthquakes due to the potentially catastrophic consequences for infrastructure and public safety, with the damage potentially hampering recovery and resupply efforts. In 1968, a 6.5 magnitude earthquake centred on Meckering, Western Australia caused significant damage, including cracked roads and railway twisted and buckled railway lines.[18]

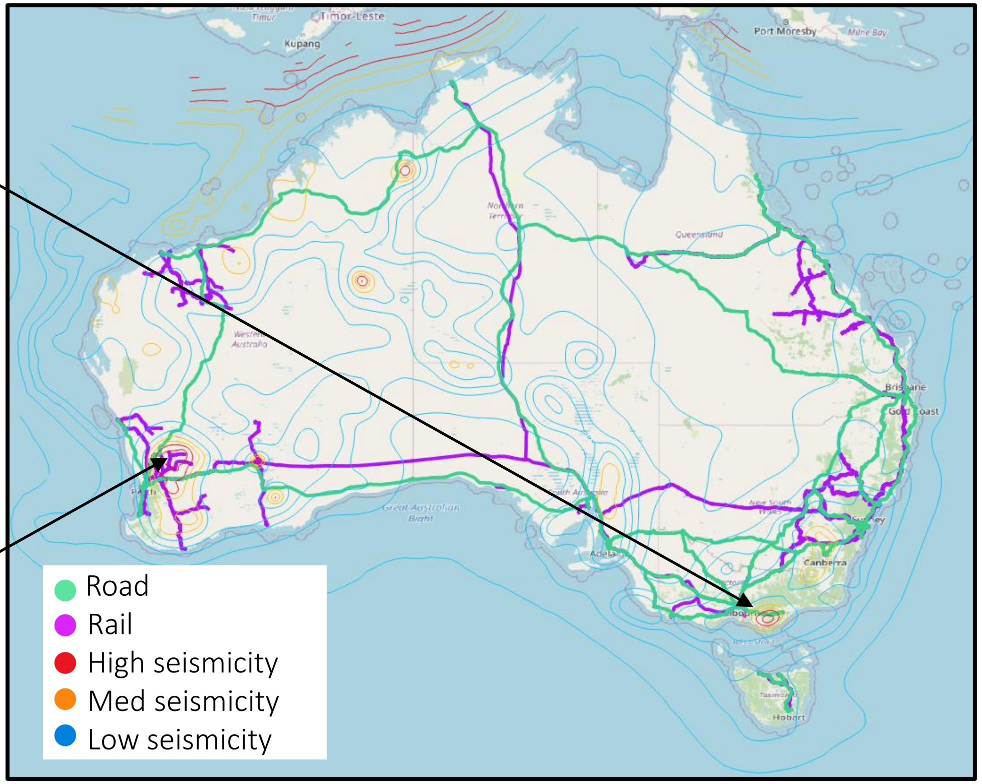
Key supply chain assets may also be disproportionately located on lands susceptible to earthquake damage. For example, port rail infrastructure (including yards, depots and administration buildings) may be built on reclaimed soft alluvial soil susceptible to subsidence and localised liquefaction.[19] Coastal facilities are also exposed to tsunami risk, which is driven by offshore seismic activity. According to the Geosciences Australia Probabilistic Tsunami Hazard Assessment (PTHA), north-western Australia is at greatest risk from tsunami; however, rail and road freight infrastructure is sparse in this area.[20] While highly unlikely, consequences for freight could be significant should a major tsunami event impact the Australian east coast.

Risk	Risk Rating	Confidence Rating
Earthquake or tremor leading to structural damage and closure of bridges	Med	High
Earthquake or tremor leading to foundation rupture due to soil deformation, potentially resulting in tunnel collapse	Med	High
Earthquake or tremor leading to high levels of dynamic vibration, compromising the integrity of retaining walls	Low	Med
Earthquake or tremor causing cracking, potholes and/or slippage of pavements	Low	High
Earthquake or tremor damaging track components, potentially resulting in potential prolonged closure	Med	Med
Earthquake or tremor resulting in damage to signalling equipment	Low	Med
Earthquake or tremor resulting in damage and/or destabilisation of cranes	Low	Med
Tsunami results in inundation coastal road and rail supply chain linkages, resulting in total closure and significant work to reopen	Med	Low

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*

High seismicity, VIC (extract from dashboard)

High seismicity, WA (extract from dashboard)



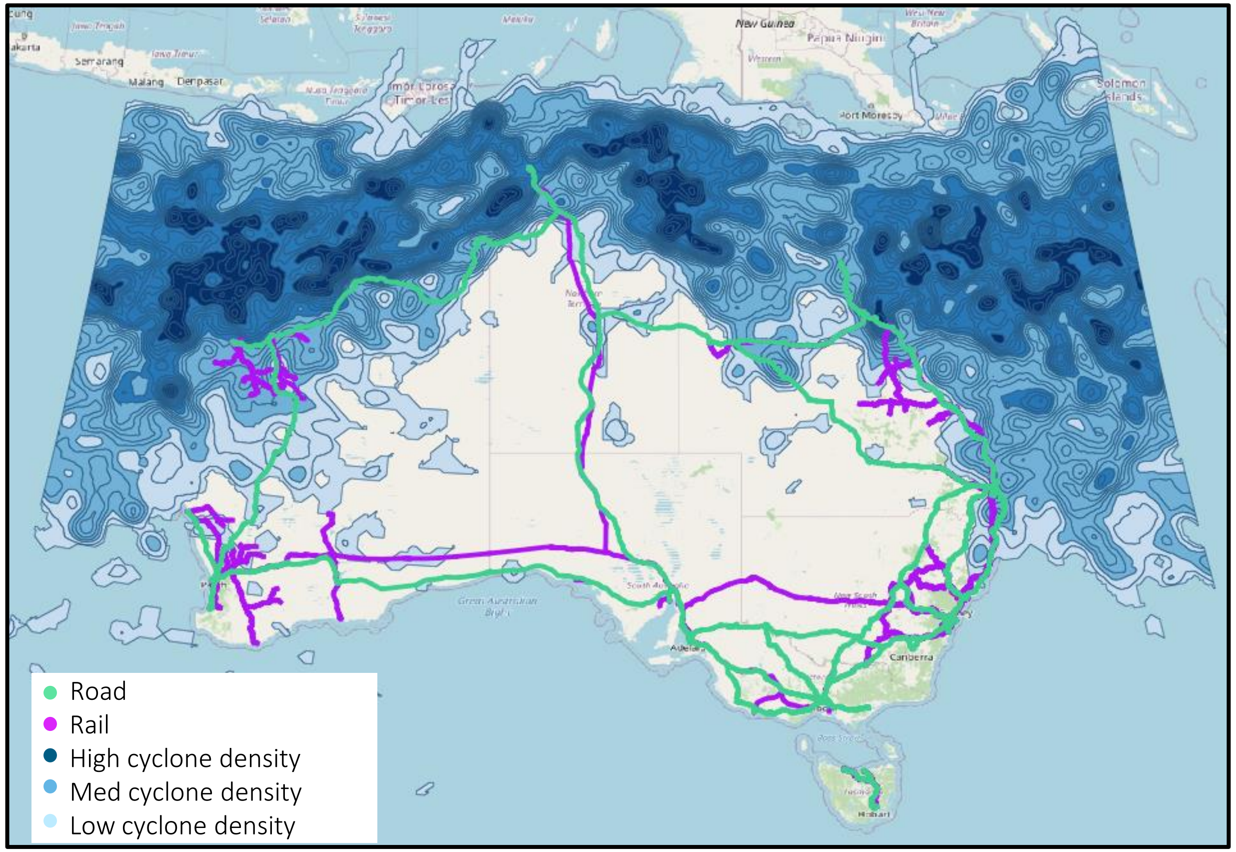
Risk summary – cyclones and storms

Given the interaction of extreme winds, intense rainfall, lightning and potential storm surges, cyclones can create significant disruption to road and rail infrastructure. In 2015, Cyclone Marcia washed away several segments of Aurizon's Moura railway line, which is a key component of the Central QLD Coal Network. Due to power failures, control centres had to run on emergency systems for a week. It took a month to fully repair the damage, and cost an estimated $28 million.[21] Similarly, in 2017, Cyclone Debbie in north Queensland caused the closure of over 150 roads due to debris and floodwaters for at least one day. Power was also interrupted due to the cyclone, creating further disruptions to local infrastructure.[22]

While north-eastern and north-western Australia are prone to seasonal cyclones, storms can affect road and rail networks nationally. Recent storms and flooding in south-east Queensland and much of NSW has been driven by East Coast Lows (ECL), which are a type of extratropical cyclone. There is evidence to suggest ECLs may become more severe due to climate change, and that cyclone tracks are gradually shifting southward,[23] increasing the likelihood of a major event in South East Queensland where infrastructure has not been designed to the same levels of cyclone resistance as in further north.

Risk	Risk Rating	Confidence Rating
Strong winds and high river flows resulting in aeroelastic instability and structural damage of bridges	Med	High
Damage to retaining walls caused by wind loads on attached fence panels	Med	Med
Extreme winds and flying debris damaging signalling and ITS equipment, resulting in delays and disruptions to freight flows	Low	Med
Damage to substation from high winds and debris, disrupting power supply to signalling and ITS	Low	Low
Lightning strike to signalling equipment, resulting in outages and potential for delays or temporary track closure.	Low	High
High winds, falling tree limbs and flying debris resulting in damage to signalling equipment and overhead wires, resulting in temporary track closures	Low	High
Extreme winds exceed operating thresholds of cranes and/or lifts, resulting in temporary disruption or more prolonged disruption if damage occurs	Low	High
Extreme winds result in movement of stored goods and/or toppling of stacked containers, resulting in damage and temporary delays	Med	High

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*



Risk summary – extreme heat

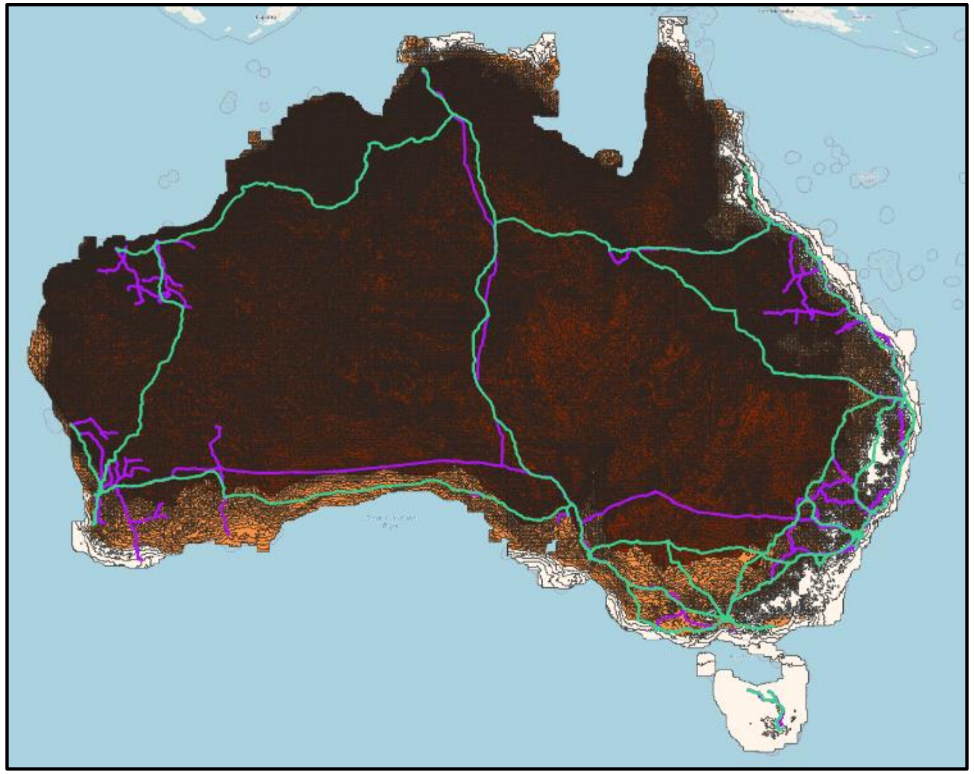
Extreme heat conditions are a well-established issue for rail operations. Speed restrictions are instigated at pre-established thresholds due to multiple factors, including the risk of bushfires generated by sparks, and track buckling due to thermal expansion of the rail. The temperature threshold for speed restrictions varies across states, territories and networks depending on factors such as the neutral stress temperature of rail and the presence of vegetation in the rail corridor. Overheating is also common for rolling stock, and signalling systems have been known to malfunction due to overheating signalling boxes, which often lack mechanical cooling.

Road networks are historically less sensitive to high temperatures, although trucks are more prone to overheating under such conditions. In extreme cases road surfaces have been known to melt, with parts of the Hume Freeway melting in Victoria in 2018 and causing bitumen to stick to passing tyres.[24]

As electrical infrastructure is also vulnerable to extreme heat conditions, the increase of intelligent transport systems (ITS) (e.g. variable speed limit signage) in road networks potentially heightens the potential impacts of heatwaves. A shift towards battery electric trucks and trains is also relevant, with the potential for battery operating performance to decline sharply at higher temperatures (e.g. 40C+). This is particularly relevant due to projected increases in heatwaves due to climate change over coming decades.[25]

Risk	Risk Rating	Confidence Rating
Extreme heat conditions exceeding design parameters of asphalt pavement, resulting in melting and accelerated wear (e.g. rutting on heavy vehicle routes)	Low	Med
Extreme heat conditions exceeding design parameters signalling and ITS equipment causing malfunctions, resulting in delays and disruptions to freight flows	Low	Med
Extreme heat conditions result in overheating of electrical substation(s), resulting in potential disruptions to signalling and ITS (most relevant for substations without mechanical cooling)	Low	Med
Extreme heat conditions resulting in rail speed restrictions and associated freight delays	Med	High
Extreme heat conditions exceeding the track neutral stress temperature, causing lateral buckling of tracks, resulting in closure of corridor unless passing loop available	Med	High
Extreme heat resulting in sagging of overhead wires on routes shared with electrified passenger services, potentially affecting safe running of freight services	Low	High
Malfunctioning of signalling equipment during extreme heat events, particularly in signalling boxes with little shade or mechanical cooling	Low	High
Extreme heat conditions result in overheating and malfunctioning of locomotives, resulting in delays	Med	Med
Extreme heat conditions exceed operating parameters of future battery electric trains, resulting in reduced range and associated delays	Med	Low

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*



Road
Rail
>30 days 35°C+
5-10 days 35°C+
0-5 days 35°C+

This map shows the average number of days per year exceeding 35°C dry bulb temperature (the standard definition of a 'hot day') between 1986 and 2005.

35°C was chosen because a consistent spatial dataset was available nationally. However, in practice, operational challenges for rail operations (e.g. speed restrictions) are more common closer to 40°C, with requirements varying across Australia.

Also note that changes to historic averages due to climate change are not included in this dataset.

Risk summary – major electricity disruption

Widespread energy supply disruptions are uncommon in Australia, with the Australian Energy Market Commission's reliability panel requiring at least 99.998% of forecast customer demand to be met each year. However, the energy sector is at the core of the climate change agenda, being susceptible to both the physical risks as result natural hazards that may be exacerbated by climate change, and transition risk as Australia's energy mix shifts away from fossil fuel and towards clean energy sources. This contributes to an uncertain future for grid reliability.

Road and rail infrastructure has grown increasingly reliant on electricity, accelerated by the advent of Intelligent Transport Systems and connected vehicles. Tunnels, signalling systems, battery electric rolling stock, and intermodal terminal operations are all potentially vulnerable to power outages, although the actual level of disruption to road and rail networks would depend on power supply redundancy measures in-place (e.g. uninterruptible power supplies; backup generators).

Risk	Risk Rating	Confidence Rating
Outages to signalling and ITS equipment, resulting in delays and disruptions to freight flows	Med	Med
Disruption to signalling, resulting in temporary delays	Med	Med
Disruption to services on electrified metropolitan networks, resulting in delays for services operating in shared corridors	Med	Med
Electricity supply disruption affects operation of cranes and lifts, temporarily delaying loading/unloading	Low	Med
Major electricity supply disruption limits capacity to recharge future battery electric trains and trucks, resulting in delays	Med	Low

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*

Impact of severe weather on energy systems

The impacts of weather on energy systems can already be significant. In September 2016, the entire state of South Australia lost power due to a one-in-50 year storm causing catastrophic damage to power infrastructure.[26] Over the last 10 years there have been several instances of extreme weather-related blackouts to hundreds of thousands of homes in Australia.

The 2017 Finkel Review into the Future Security of the National Electricity Market found that, in response to increased severity of extreme weather due to climate change, a strategy to improve integrity of energy infrastructure and the accuracy of supply and demand forecasting would be necessary.

The changing role of electricity in transport

Electricity is increasingly foundational to the operation of transport networks. While few freight networks in Australia are electrified (a notable exception is much of the Central Queensland Coal Network), where electrified commuter services share a corridor with freight vehicles, disruption to passenger trains will have knock-on impacts on the rail freight network. The growth of electric vehicles, predictive maintenance systems, ITS (e.g. variable speed limit signage) and advanced train management systems is also increasing the potential impacts of any disruption to the power network and underscores the need for robust redundancy provisions.

Many commuter trains already rely on robust electricity supply to function. The International Energy Agency projects rail transport to become almost entirely electrified by 2050.[27] The trial of battery-electric locomotives at BHP's Western Australia Iron Ore rail network[28] is indicative of a larger movement towards electric trains in industrial freight contexts.[29] With reliance on electricity increasing, the National Energy Market will need to be safeguarded against disruption to ensure reliable rail networks.

Risk summary – extremist event

Although there are no known historic attacks specifically targeting freight movements, extremist events targeting high-profile locations can cause widespread disruption. Critical infrastructure providers have obligations to consider such risks under the amended Security of Critical Infrastructure Act 2018, and broader counter-terrorism efforts also play an important role in the resilience of Australia's freight task.

Risk	Risk Rating	Confidence Rating
Extremist events targeting major bridges, resulting in structural damage and closures	Med	Med
Extremist events targeting tunnel infrastructure, resulting in closures	Med	Med
Extremist events targeting electrical substations, potentially resulting in outages for road systems reliant on power (e.g. signalling and ITS)	Low	Low
Extremist event targeting intermodal terminal results in damage and prolonged closure	Med	Low

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*

Credible intelligence, assessed by National Terrorism Threat Advisory System, indicates that individuals or groups have developed both the intent and capability to conduct a terrorist attack in Australia.[30] Therefore the likelihood of an act of terrorism occurring in Australia alert level is ***Probable*** (level three of five on the scale).

Such events are no longer considered to be solely the domain of malicious foreign or religiously-motivated actors.[31] Rather, it is acknowledged that radicalisation can be motivated by a range of reasons and sources. The advent of the digital age has also increased the reach of radicalisation and recruitment.

While there are thought to be no historic terror attacks in Australia specifically directed at freight infrastructure, events targeting high-profile locations can nonetheless affect freight flows. For example, London has experienced two significant attacks on its underground public transportation system in 2005 and 2017, and attacks on London Bridge in 2017 and 2019 both resulted in closure of a major thoroughfare. Damage to feeder cables used to provide two-way radio traffic inside tunnels and buildings communications during the 2005 bombings resulted in outages of rail network signalling equipment and temporary delays of emergency and transport systems reliant on the transfer of data through the network.[32]

Rail transportation has several unique features making it inherently vulnerable to attack. Rail networks traverse dense urban landscapes that offer multiple attack points, and freight networks 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 cargo could lead to catastrophic damage on surrounding infrastructure. Attacks targeting passenger rail could also affect freight in areas with shared corridors.

An attack focused on an intermodal terminal (IMT) could also cause flow-on disruptions for supply chains, as they provide a node through which significant volumes of freight pass. The extent of impact would depend on the availability of alternative facilities, and it could be argued that an IMT being targeted is unlikely as targets higher in the public consciousness would be favoured.

Risk summary – cyber threat

Malicious cyber activities against Australian interests are increasing in frequency, scale, and sophistication. With the growing use interconnected Operational Technology (OT) and Internet of Things (IoT) devices it is increasingly possible for hackers to gain or deny access to transport operational systems using techniques such as malware, ransomware and distributed-denial-of-service (DDOS) attacks. Potentially vulnerable systems include: rail and road signalling; road sensors and Lidar; power supplies, and train control systems. While such systems offer significant efficiency and safety benefits when fully operational, they also increase the potential attack surface for malicious actors. Designing these new systems in a safe-to-fail manner with adequate contingency plans for manual operation will be critical.

Case study – Major Logistics Company

Australia is the sixth most targeted country for cyber-attacks, with 16 significant attacks between May 2006 and June 2020. Furthermore, the Australian Cyber Security Centre (ACSC) recorded a 15 per cent increase in ransomware cybercrime reports in the 2020–21 financial year.[33] A highly relevant example is the ransomware attack on a major logistics company at the beginning of 2020. A suspected phishing and password spray attack from Russian based hackers led to the lockdown of the organisation's IT systems over across multiple sites and business units.[34]

The company faced over a month of costly disruptions to network freight operations of critical supplies, requiring temporary transition to a range of manual processes. Communities experienced flow-on impacts from delays of personal goods and inaccuracy of the organisation's track and trace service due to the operating system shutdown. This case illustrates the interdependencies between IT (e.g. logistics management) and connected services and operational technology (OT) required to operate transport facilities, deliver services and goods.

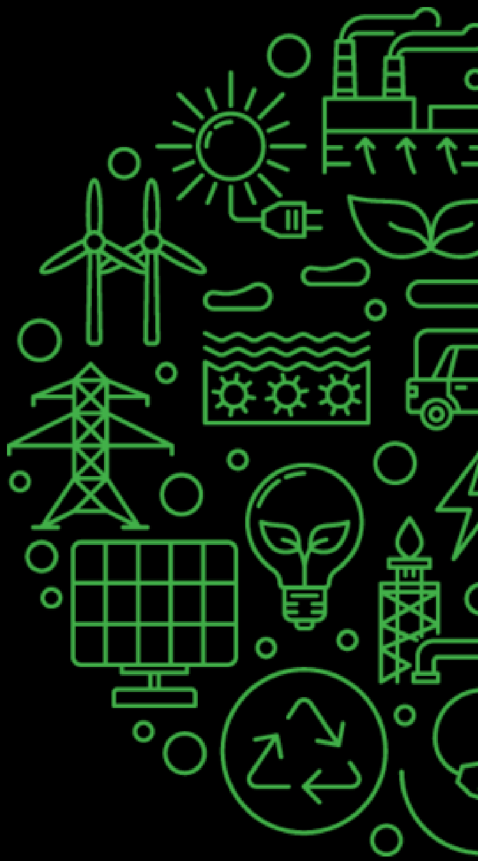
Risk	Risk Rating	Confidence Rating
Malicious cyber activities (e.g. phishing, ransomware, DDOS attacks) causing disruptions to bridge management systems (e.g. variable speed limit signs; drawbridge controls)	Med	High
Malicious cyber activities (e.g. phishing, ransomware, DDOS attacks) directed at signalling and ITS, potentially causing outages	Med	Med
Malicious cyber activities (e.g. phishing, ransomware, DDOS attacks) targeting electrical supply infrastructure, potentially resulting in outages for road systems reliant on power (e.g. signalling and ITS)	Med	Med
Malicious cyber activities (e.g. phishing, ransomware, DDOS attacks) directed at rail freight operator and/or train control systems, potentially resulting in delays and safety risks	High	Med

**Overall priority rating, based on current day likelihood and consequence of a reasonable worst case scenario event*

The table below summarises some of the key technological developments that have the potential to improve resilience to some natural hazard events, while also creating new cyber vulnerabilities.

Potential Cyber attack Entry Point	Description
Future Railway Mobile Communication Systems (FRMCS)	FRMCS is a new global standard for rail sector communications currently under development. Broadband and high bandwidth 5G networks are expected to enable use cases such as object detection on the track, on-board condition monitoring, passenger communications and trackside condition monitoring.[35]
Advanced Train Management System (ATMS)	ATMS is a digital train management solution being implemented by ARTC, with real-time monitoring of trains with GPS and mobile technology. [36] ATMS drives improvements in operational efficiency and safety, potentially improving communications related to natural hazard events. However, it also provides an additional cyber attack surface compared to historic radio-based operations.
Autonomous Trains	First trials of fully driverless freight trains are in full effect with Rio Tinto's Pilbara iron-ore railway network being the world's first automated heavy-haul freight railway. The automated network developed and delivered an automated train management system including a centralised vital safety server, and supports the safe and flexible management of train movements. In addition, the locomotives are fitted with collision detection systems; automatic train protection technology, which controls train speed and adheres to speed limits; and an onboard video camera to record the forward view of the train.[37]
Adaptive Traffic Systems	Sydney Coordinated Adaptive Traffic System (SCATS) is a traffic control system designed to optimise traffic flow. Intelligent algorithms process real-time data to adapt traffic signal timings that respond to unexpected conditions, predict traffic patterns and keep traffic moving. The result can be a reduction in congestion, shorter journey times and increased safety and productivity.[38]

Conclusion



Conclusion

In support of the Review, this report has provided a stocktake of:

- Risks that impact on road and rail supply chains, including natural disasters and human-induced events
- Government and industry initiatives recently completed, underway or planned that may mitigate these risks.

A mixed-methods approach was used to identify how rail and road infrastructure could be physically damaged, disrupted or degraded by nine types of natural and human-induced hazard. The study also undertook preliminary prioritisation of these risks using an ISO 31000-aligned consequence and likelihood framework.

Key findings include:

Bushfires and flooding have been identified as the two natural hazards posing the most significant risks to Australia's road and rail supply chains. This reflects the potential for these events to cover an extremely large geographic footprint, resulting in widespread disruptions with knock-on effects across multiple states and territories.

Cyber attacks on transport-related operators' ICT systems were also identified as a risk to freight supply chains with potentially widespread consequences. This was observed through the phishing and ransomware attacks on logistics company systems, with the attack surface for similar incidents increasing as more transport infrastructure is controlled remotely (e.g. connected vehicles; Future Railway Mobile Communication Systems).

Transport infrastructure has grown **increasingly reliant on electricity**, with tunnels, ITS, battery electric rolling stock, and IMT operations all potentially vulnerable to power outages. While widespread energy supply disruptions are uncommon in Australia, the Finkel Review acknowledged the growing risks to the sector from physical risks as result natural hazards that may be exacerbated by climate change. The transition of Australia's grid towards clean energy sources lacks local precedent, resulting in uncertainty for grid reliability.

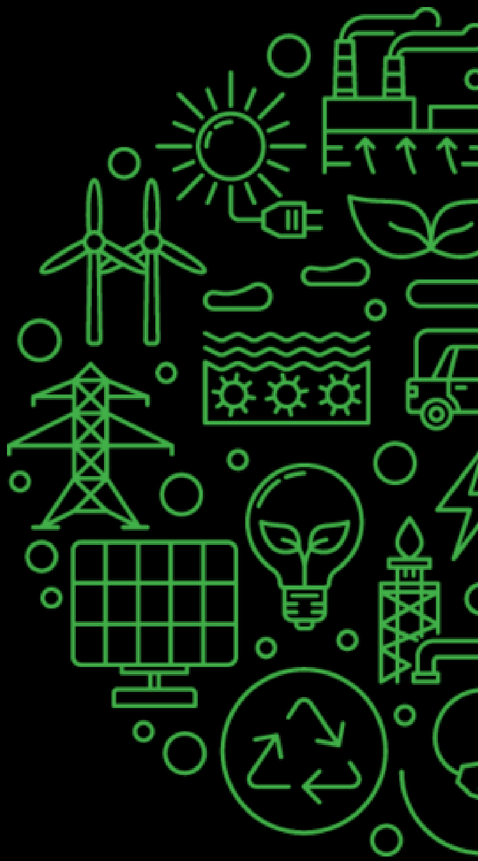
Rail networks typically have lower levels of adaptive capacity than roads when faced with natural or human-induced disruptions, as re-routing options are limited, particularly outside major urban centres. Following flooding in 2022 of the Trans-Australian railway, only 'land bridging' or wholesale shift to road haulage and shipping was viable.

Even where alternatives do exist, the ability to re-route can be constrained by contracted schedules under the ARTC Master Train Plan and limited flexibility in timetabling.

The resilience of Australia's freight task is supported by a range of **Commonwealth, state, territory and private sector policies and strategies**. Infrastructure bodies (e.g. IA, INSW) increasingly place a strategic emphasis on investment in infrastructure resilience, the recent *Security Legislation Amendment (Critical Infrastructure Protection) Act 2022* introduces updated obligations on responsible entities to enhance CI management, and infrastructure betterment provisions are becoming more common under Australia's Disaster Recovery Funding Arrangements 2018.

The report identified a range of resilience-related initiatives varying from specific infrastructure investments that add redundancy to networks (e.g. West Gate Tunnel in Melbourne), through to capacity building programs for government employees around natural hazard and climate risk management (e.g. NSW Climate Risk Ready program). Key **gaps and challenges within the suite of initiatives** include duplicated effort across jurisdictions, limited quantification of resilience costs and benefits in business cases, and balancing the need to quickly restore supply chain linkages following disasters with investments in betterment.

Glossary and references



Glossary

Term	Abbreviation (where applicable)	Definition
Adaptive capacity		The capacity of systems to adjust to potential damage. Quantified in this report to define whether viable alternatives exist within the road network to re-route freight in the case of disruption.
AdBlue		A commercial name for diesel exhaust fluid used to reduce air pollution created by diesel engines.
Advanced Train Management System	ATMS	A digital train management solution with real-time monitoring of trains with GPS and mobile technology.
Annual exceedance potential	AEP	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Attack surface		Points of entry for an unauthorized user to enter or extract data from an environment. Relevant to cyber attacks.
Australian Government Crisis Management Framework	AGCMF	The Australian Government Crisis Management Framework (AGCMF) outlines the Australian Government’s approach to preparing for, responding to and recovering from crises.
Australian Rail Track Corporation	ARTC	A government-owned statutory corporation operating one of Australia's largest rail networks.
AUSTROADS		Austroads is the collective of the Australian and New Zealand transport agencies, representing all levels of government.
Autonomous vehicle		Autonomous vehicles can perform functions without human intervention. Semi-autonomous vehicles still require human input but have the capability to conduct some functions independently.
Bureau of Infrastructure and Transport Research Economics	BITRE	Part of the Data, Analytics and Policy Division of the Department of Infrastructure, Transport, Regional Development and Communications.
Bushfires		Bushfires and grassfires are common in Australia. While grassfires are fast-moving and have low or medium intensity, bushfires move slower but have a higher heat output. Bushfires have the potential to cover an extremely large geographic footprint, leaving them capable of major supply chain disruptions.
Climate change		Change in global or regional climate patterns, specifically referring to changes apparent from the 20th century onwards, generally accepted to be a result of human activity, primarily fossil fuel use.
Commonwealth Scientific and Industrial Research Organisation	CSIRO	The Australian Government agency responsible for scientific research.
Critical infrastructure	CI	Assets that are essential to the functioning of society and economy.
Cyber attack		An offensive attempt to damage a computer network or system. In this report, cyber attacks cover phishing, ransomware and DDOS attacks.
Cyclones		Cyclones, also known as typhoons or hurricanes, are intense circular storms originating over warm oceans.
Department of Infrastructure, Transport, Regional Development and Communications	DITRDC	The Australian Federal Government department responsible for policy and programs relating to infrastructure, transport, regional development and communications.
Distributed Denial of Service Attack	DDoS Attack	A cyber attack in which the perpetrator makes a resource unavailable to its intended users.
East Coast Lows	ECL	East coast lows are intense low pressure systems occurring off the eastern coast of Australia. They can generate gale or storm force winds, heavy widespread rainfall and rough seas with heavy swells over coastal and ocean waters.
eCommerce		Commercial transactions conducted electronically, using the internet.
Electricity disruption		Interruption of power supply. This can be a compound result of other hazards or may occur independently.
Exposure		A lack of protection from something harmful. Quantified in this report to define segments of the rail and road network that are in locations proximate to hazards.

Glossary

Term	Abbreviation (where applicable)	Definition
Extreme heat		Periods of hot weather relative to normal temperatures for the season. Also referred to as a heatwave, periods of extreme heat have the potential to negatively affect human health and infrastructure.
Extremist event		The use of violence and fear to achieve and ideological aim. Extremist events is a deliberately vague descriptor, which cover terrorism and other deliberate and acute acts of violence.
Flooding		Floods can take a range of forms: The most damaging recent events have been mostly riverine flooding, which occurs when large volumes of intense rainfall exceed the carrying capacity of watercourse. As shown in the map below, vast extents of central Queensland form floodplains that are periodically inundated in this way. Closer to the coast, coastal inundation can be caused by a storm surge as a result of a tropical cyclone, a tsunami or a high tide coinciding with higher than normal river levels. In built-up areas, surface water flooding can also occur when drainage systems are unable to keep up with the rate/intensity of rainfall, leading to overflows.
Freight task		Measures the activity undertaken by road, rail and coastal shipping operators in Australia.
Hazard		A potential source of harm. This report uses the term to refer to human-caused and natural dangers.
Information and Communications Technology	ICT	Information technology that stresses the role of unified communications and integration of telecommunications and computers.
Information technology		Technology related to data and information flows.
Initiatives		Interventions designed to contribute to the resilience of road and rail supply chains.
Intelligent Transport Systems	ITS	Systems supporting the coordination of transport infrastructure. ITS uses advanced information and communication technologies to collect information on road conditions, to help system managers and road users make informed decisions.
Intermodal Terminals	IMT	A terminal specialised to transfer cargo from one mode of transport to another.
International Organization for Standardization guidelines for risk management	ISO 31000	A family of standards relating to risk management codified by the International Organization for Standardization.
Just in time		An inventory system that aligns supply orders with production schedule, reducing in-house storage requirements and sourcing materials on an as-needs basis.
Landslide		Also referred to as landslips. A downslope of a mass of rock, debris, earth, or soil. Gravity combines with other stresses to exceed the strength of the material that forms a slope, mountain or cliff.
National Asset Centre of Excellence	NACoE	An initiative by the Department of Transport and Main Roads (Queensland) and the Australian Road Research Board. It is comprised of research programs regarding pavements, asset management, structures, network operations, road safety, heavy vehicle management and sustainability.
Operational technology		Operation of physical and mechanical processes and the hardware that conducts these processes. As operational technology is increasingly automated, it is increasingly vulnerable to electricity disruption and cyber attacks.
Probabilistic Tsunami Hazard Assessment	PTHA	A model developed by Geosciences Australia to determine the frequency with which tsunamis of any size occur around the Australian coast.
Resilience		The capacity to anticipate and respond to hazards and disturbances.
Risk		The likelihood of a hazard to cause harm.
Rolling stock		Refers to railway vehicles, including both powered and unpowered vehicles: for example, locomotives, freight and passenger cars.

Glossary

Term	Abbreviation (where applicable)	Definition
Seismicity		The occurrence or frequency of earthquakes in a region. Seismicity covers both earthquakes and tsunamis.
Sensitivity		The degree of susceptibility to stimulation. Quantified in this report to define segments of the rail and road network that carry significant volumes of freight, which could be disrupted by hazards.
Spatial data		Data describes incidences relative to their location.
Statistical Area 3 & 4	SA3, SA4	The Australian Bureau of Statistics publishes statistics within regional frameworks called Statistical Areas. They are hierarchically structured according to granularity with SA1 being the smallest geographic area, and SA4 being the largest geographic area. SA3 is designed to generate regional-level data of populations between 30,000 and 130,000 people, representing functional areas of regional towns and cities. SA4 are the largest sub-state regions and represent labour markets and the functional area of Australian capital cities.
Sydney Coordinated Adaptive Traffic System	SCATS	A type of traffic control system designed to optimise traffic flow.
Transport Logistics - TraNSIT	TraNSIT	A mapping tool developed by CSIRO to produce information on freight paths, detailed transport costs and critical link analysis to inform infrastructure investment and regulatory decisions.
Urea		A key component of AdBlue
Vulnerability		Exposure to the possibility of harm. This report quantifies vulnerability as a product of exposure, sensitivity and adaptive capacity to inform an aggregated risk rating.
Widespread		Impacts covering multiple SA3s (large geographic area) or a large population.

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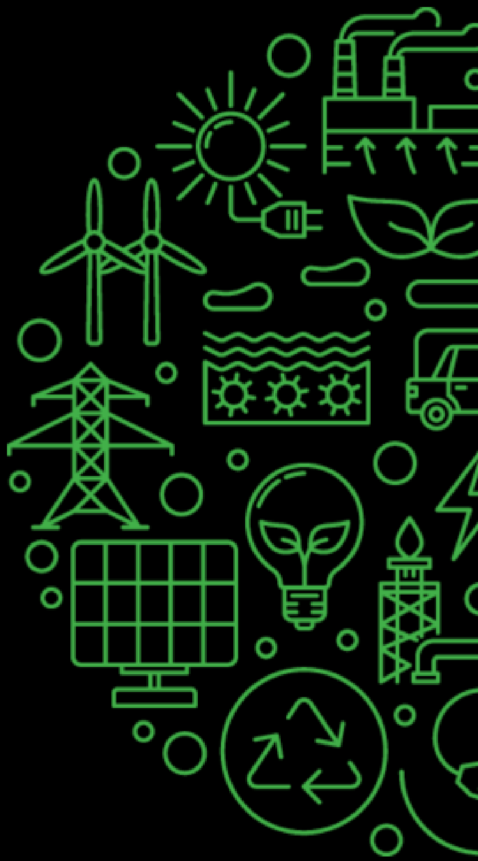
Appendix 1 – assessment method



Establishing the context

Define the external and internal parameters for the assessment, including scope.

Establish the context
↓
Risk identification
↓
Risk analysis

Desktop research undertaken focusing on:

- Policy context
- Taxonomies for conceptualising natural hazard and disaster risk
- Typologies of rail and road asset classes and sub-classes (e.g. Transport for NSW)
- Reports providing information on existing infrastructure and supply chain resilience initiatives
- Reports offering a view on priority natural hazard risks in Australia.

Table showing whether hazards were noted in state-level risk summaries.

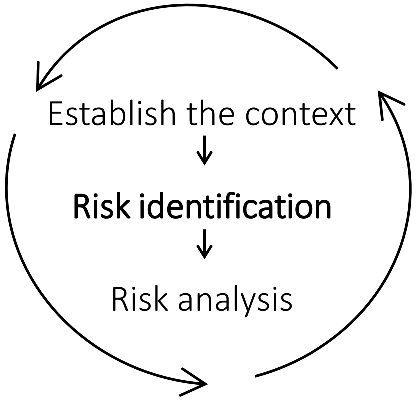
Hazards	VIC	NSW	QLD	WA	ACT	NT	SA	TAS	Could directly damage or disrupt road or rail
Bushfire	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Earthquake	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Electricity supply disruption	Yes	No	No	No	Yes	Yes	No	No	Yes
Emergency animal disease	Yes	No	No	Yes	Yes	Yes	Yes	No	No
Emergency plant pest	Yes	No	No	Yes	Yes	Yes	Yes	No	No
Flood	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Gas supply disruption	Yes	No	No	No	No	No	No	No	No
Hazardous materials (Chemical Substances - HAZMAT)	Yes	No	No	No	No	Yes	No	No	Yes
Heatwave	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maritime emergency	Yes	No	No	No	No	Yes	No	No	No, but poses up/downstream risks
Mine emergency	Yes	No	No	Yes	No	Yes	No	No	No
Pandemic influenza	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No, but poses up/downstream risks
Storm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water supply disruption	Yes	No	No	No	No	Yes	No	No	No, but poses up/downstream risks
Infrastructure Failure (Communication, dam flood, transport)	No	Yes	No	No	Yes	Yes	No	No	Yes, but this study to focus underlying causes of failure
East Coast Low	No	Yes	No	No	No	No	No	No	Yes
Biosecurity (includes exotic/endemic animal, plant and pest emergencies)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No, but poses up/downstream risks
Tsunami	No	No	Yes	No	No	No	No	No	Yes
Landslide	No	Yes	No	No	No	No	No	No	Yes
Coastal Erosion	No	Yes	No	No	No	Yes	No	No	Yes, but only in isolated locations
Water or Sewerage Emergency	No	No	No	No	No	Yes	No	No	Yes
Riverine Flooding	No	No	No	No	No	Yes	No	No	Yes (captured under 'flooding')
Tropical Cyclones	No	No	No	No	No	Yes	No	No	Yes
Coastal Inundation	No	No	No	No	No	Yes	No	Yes	Yes (captured under 'flooding')
Air crash	No	No	No	No	No	Yes	No	No	Yes, but extremely rare
Cyber attack (NTG enterprise ICT environment	No	No	No	No	No	Yes	No	No	Yes
Terrorism	No	No	No	No	No	Yes	No	No	Yes
Rail Crash	No	No	Yes	Yes	No	No	No	No	Yes, but this study to focus underlying causes
Road Crash	No	No	No	Yes	No	No	No	No	Yes, but this study to focus underlying causes

* Yes - Hazard was noted in Risk Assessment Summary
* No - Hazard was not noted in Risk Assessment Summary, however can still apply to State and Territory

Proposed hazards	Rationale for inclusion
Bushfire	Relevant to all states, territories and asset classes. Also include qualitative commentary on other sources of fire.
Seismicity	Low likelihood but potentially catastrophic consequence event - covered by all state/territory assessments. Includes earthquake (spatial) and tsunami (qualitative)
Flooding	Covered by all state/territory assessments except SA
Extreme heat	Relevant to all states, territories and especially rail infrastructure
Cyclone & storms	Considered in QLD, NT and WA assessments – potentially growing relevance for SE QLD and Northern NSW
Landslide	Exposure not widespread but affects some important linkages particularly in NSW
Cyber threats	*Qualitative.* Covered by state/territory assessments and IA study. Includes data outages, ransomware, phishing, etc.
Electricity interruption	*Qualitative.* Addressed by VIC, ACT and QLD – exposure increasing due to multiple factors.
Extremist event	*Qualitative.* Not addressed by all state/territory assessments but potential consequences high.

Risk identification

Determine the long-list of ways that priority hazards can impact different components of road and rail infrastructure.



Risk statements reflect the range of ways in which selected hazards could impact asset classes. Each comprises a hazard, effect on infrastructure component, and consequence.

For example:

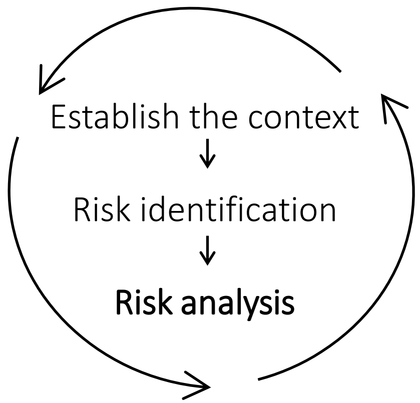
Cyber attack disrupting operation of road traffic control systems, resulting in freight delays

A long-list of risk descriptors was developed from the following sources:

- Matrix of agreed hazards and infrastructure components (informed by Transport for NSW Asset Classification System)
- *A National Study of Infrastructure Risk* (Infrastructure Australia, 2021)
- Semi-structured interview findings
- Other sources identified through literature review, for example:
    - *The impact of the 2009 heatwave on Melbourne's critical infrastructure* (McEvoy, Ahmed & Mullett, 2012)
    - *Cyber risk and insurance for transportation infrastructure* (Tonn et. al., 2019)
    - *Climate change research on transportation systems: Climate risks, adaptation and planning* (Wang et al., 2020)

Risk analysis

Undertake preliminary prioritisation of risk statements, based on available information.



An overall risk register was developed to relatively assess each risk descriptor based on current day likelihood and consequence of a reasonable worst case scenario event (see guidance to right). The register includes:

- Confidence rating (i.e. *high, moderate* or *low* depending on evidence base)
- Key geographic 'hot spots', based on the spatial assessment
- Potential interdependencies with other hazard types (e.g. a heatwave event contributing to risk of bushfire)
- Related Government and private sector risk management initiatives (current and planned).

The timeframes indicated in the consequence score are reflective of the cascading nature of interruptions to supply chains where one week of interrupted freight flows represents significant consequences. They are developed in absence of formal stakeholder consultation, and informed by the ability of freight systems to recover from disruption.

Risk ratings were informed by drawing on the **spatial assessment outputs** (natural hazards only), **desktop review findings**, and **professional judgement**.

	Likelihood	Consequence
Low (1)	May occur once in a lifetime	Impacts largely confined to a discrete region with duration less than two days
Medium (2)	Occurs a few times a generation	Impacts widespread (geographically or population) for up to one week; or Impacts localised but disruption extends longer than one week
High (3)	Occurs at least once per year	Impacts widespread (geographically or population) and it could take over one week to restore freight flows

	Low	Medium	High
Low	1	2	3
Medium	2	4	9
High	3	6	9

Confidence	Description – confidence in risk level
Low	Limited evidence / scientific consensus
Moderate	Moderate evidence / scientific consensus
High	Robust evidence / scientific consensus

Hazard	Infrastructure class	Sub-class	Risk Statement	Consequence	Likelihood	Overall Risk Rating	*Confidence Rating*	Rating rationale	Key risk hotspots
Bushfire	Both	Bridges	Bushfires causing structural damage to bridges, resulting in closures and repair costs	1	3	Med	High	Bridges made from timber are more susceptible to fire damage. Bushfire is a well-established hazard in all assessments but wooden bridges are no longer common on major freight routes, hence low consequence.	

Spatial Analysis: Value Driver Tree for Roads

Note: The methodology above describes Deloitte's vulnerability analysis. To avoid confusion, BITRE's Road and Rail Supply Chain Resilience Review does not use Deloitte's references to sensitivity and adaptive capacity, as described in this report. The Review uses a different methodology and inputs for sensitivity and adaptive capacity (using CSIRO's TraNSIT) to undertake its vulnerability analysis.

① Problem Statement

Better understand the most vulnerable segments of supply chains

② Focusing Question / **③ Analysis**

1.1 Exposure

- Project each identified hazard and intersect with heavy vehicle routes using proximity classify
- Proximity of Road/Rail Network to Hazard, classified into High, Medium and Low ranks based on the defined risk matrix.
- For each road segment calculate weighted score for all identified Hazard types. Each of the six hazards is rated an exposure score (0- 3) with extreme heat (0 -1.5) for a combined maximum total of 16.5 which is factored into the segment vulnerability score.

1.2 Sensitivity

- Generate a Origin and Destination matrix using ABS Road Freight Movements 2013-2014 (cat. No. 9223) at SA3 level and for Rail movements using BITRE supplied intermodal rail movements data (20220506 Trainline 9.xlsx).
- Calculate sensitivity cost of path using total tonnes carried on each road/rail segment by every route derived from OD Matrix
- Aggregated the total tonnes for every route on each road/rail segment
- Normalise the total tonnes carried using feature scaling method to produce a value between 0-1, 1 being the highest.

1.3 Adaptive Capacity

- For each of the road segments in scope of analysis, determine start and end point of segment based on Open Street Map network.
- With the given road segment start and end point, calculate 10 alternative routes based on the road segment not existing within OSM network. Alternative routes are calculated using K-Shortest path/Dijkstra algorithm.
- Allow the routing algorithm to search within a 50km radius of alternative paths in the event the road segment didn't exist within network.
- If a road has 0 alternative paths this would score 100%, if the road has 10 alternative paths this would be 0%, the lower the score indicates that in the event of the road being unavailable adaptive routing exists.

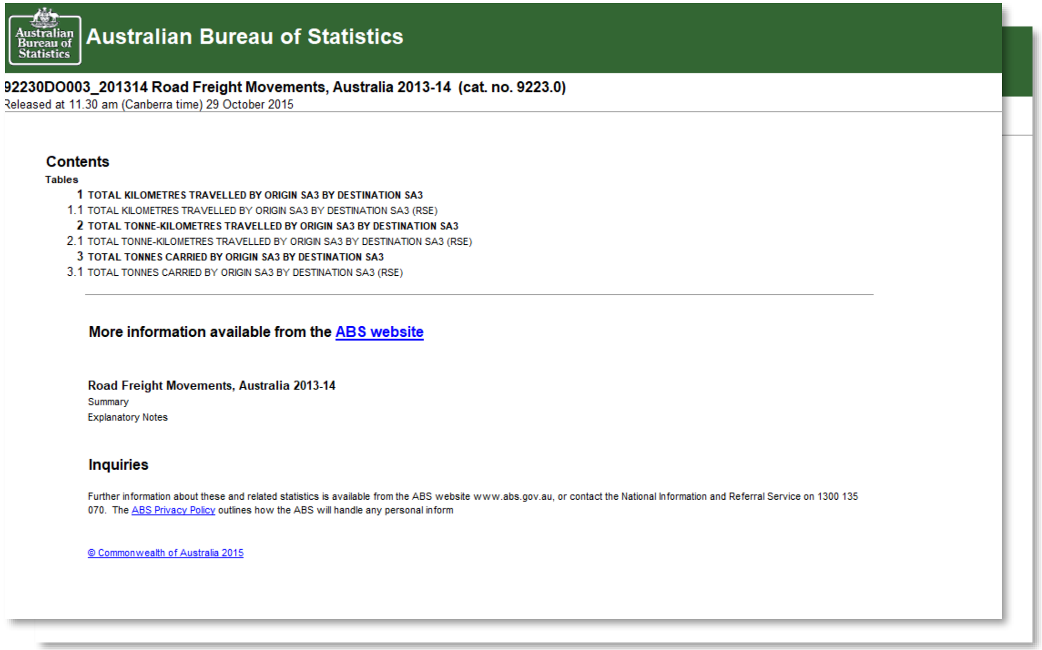
Total Vulnerability Score=

Total Exposure score (0-16.5) x Sensitivity (normalised scale 0-1) x Adaptive capacity (normalised scale 0-1)

Adaptive capacity excluded from rail

Defining the freight network

ABS Road Freight Movements, Australia 2013-14


Australian Bureau of Statistics

92230DO003_201314 Road Freight Movements, Australia 2013-14 (cat. no. 9223.0)
Released at 11.30 am (Canberra time) 29 October 2015

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2 TOTAL TONNE-KILOMETRES TRAVELLED BY ORIGIN SA3 BY DESTINATION SA3
2.1 TOTAL TONNE-KILOMETRES TRAVELLED BY ORIGIN SA3 BY DESTINATION SA3 (RSE)
3 TOTAL TONNES CARRIED BY ORIGIN SA3 BY DESTINATION SA3
3.1 TOTAL TONNES CARRIED BY ORIGIN SA3 BY DESTINATION SA3 (RSE)

More information available from the ABS website

Road Freight Movements, Australia 2013-14
Summary
Explanatory Notes

Inquiries

Further information about these and related statistics is available from the ABS website www.abs.gov.au, or contact the National Information and Referral Service on 1300 135 070. The ABS Privacy Policy outlines how the ABS will handle any personal inform

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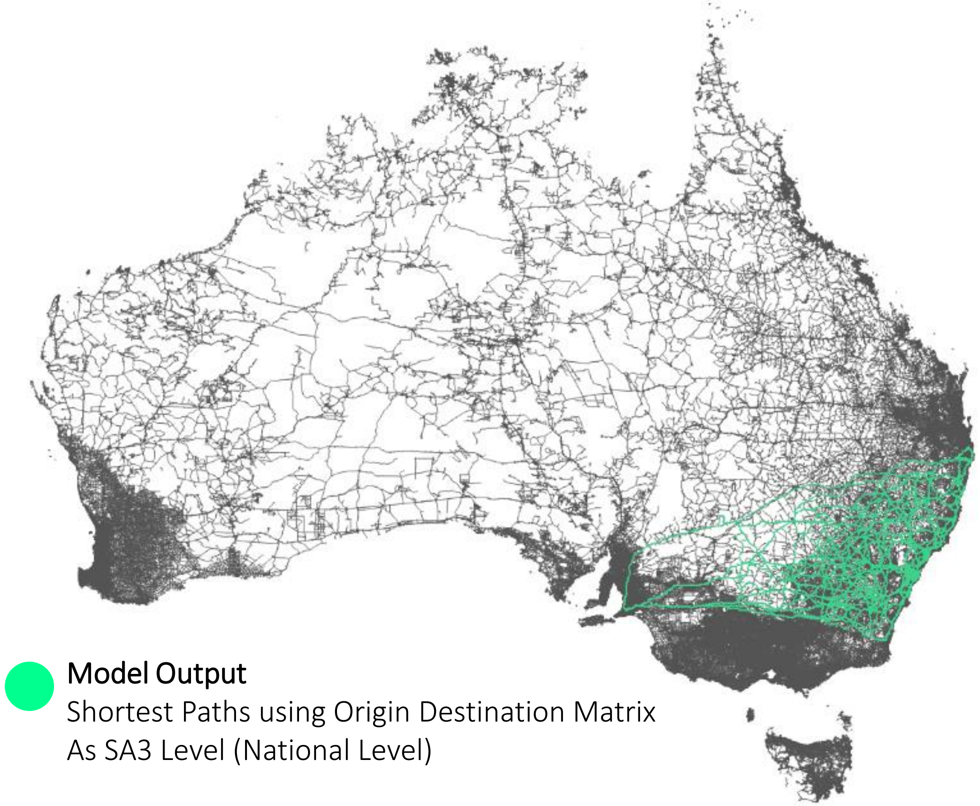


Model Output
Shortest Paths using Origin Destination Matrix
As SA3 Level (National Level)

Using the ABS product of Road Freight Movements data 2013-2014, allows for the origin and destination matrix of movements at SA3 level to be created. The model uses the centroid of the SA3 boundary to derive a latitude and longitude start/end point for each origin and destination pair. For each route **'Total Tonnes Carried'** was used to estimate the sensitivity cost of the route.

Using the ABS Road Freight Movements origin and destination matrix we generate the shortest paths using the Open Street Map Network (excluding non motorway and highway roads). The algorithm used is called Dijkstra's algorithm. Once a path has been generated, we associated the 'Total Tonnes Carried' to each road segment. If a road has multiple routes, we sum the value to work out how sensitive that part of the road network is.

Exposure

The presence of people, assets and ecosystems in places where they could be adversely affected by threats.

Freight Route | Fire Frequency (High) | Fire Frequency (Low) | Flood (1% AEP)

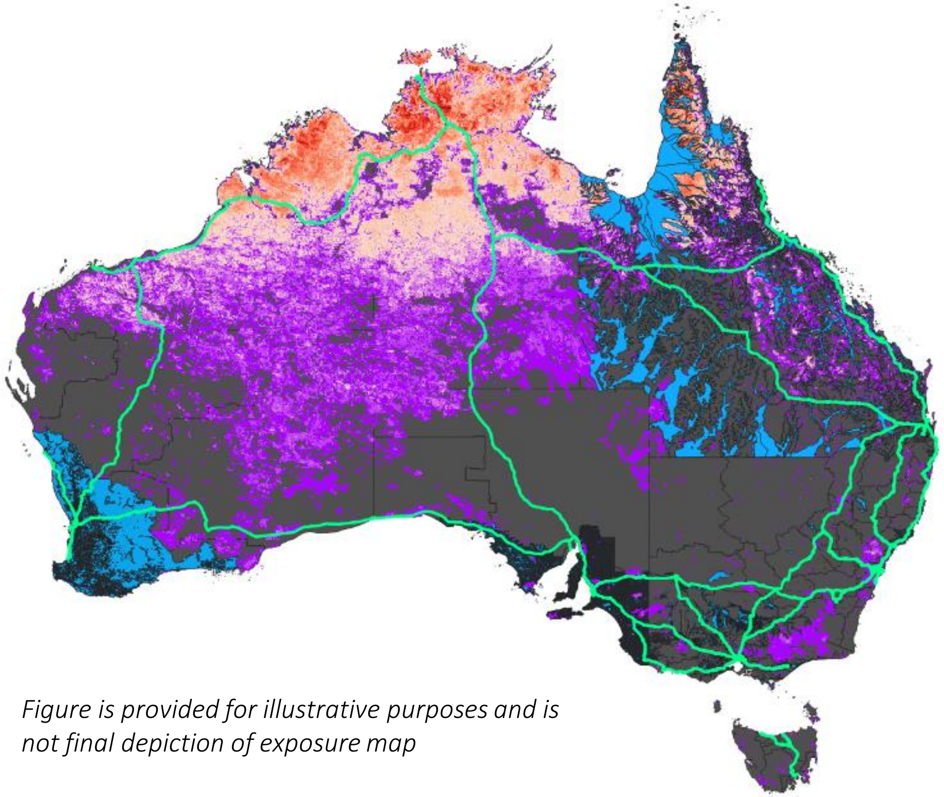
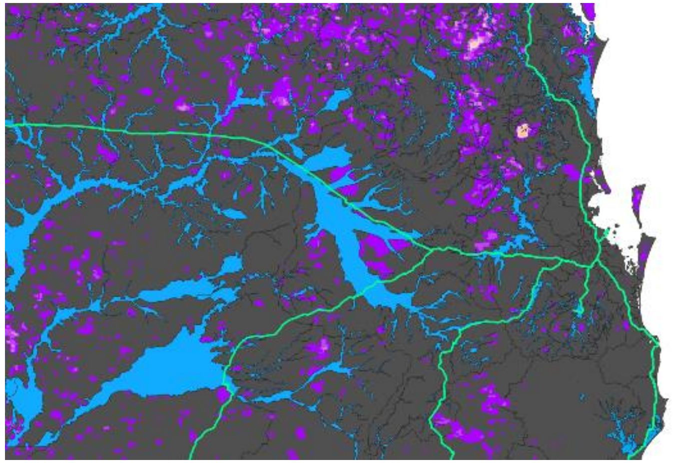


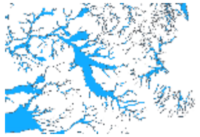
Figure is provided for illustrative purposes and is not final depiction of exposure map

Example: Flood Extent Intersecting Critical Junction



Key Freight Routes

Flood Extent



Fire Frequency

Key Freight Route Impacted

Hazard Categories Exposure Matrix & Data Sources

Dataset	State/s	Hazard Category	Field	Rationale	0 (Not Applicable)	1 (Low)	2 (Med)	3 (High)
Cyclone Intensity and Frequency Index [1]	All Australia	Cyclone	Nominal Index: Cyclone Density	Best available dataset for Australia	0: No cyclone occurrence, 1: Australian Continent	2: Low	3-8: Medium	9-16: High, 17-23: Very High
NSW Environmental Planning Instrument - Land with Development Implications due to Flood [2]	NSW	Flood	Layer Name	No nationally consistent flood dataset, requiring combined approach. This will result in some inconsistencies.		Within 1km of flood area	Within 500m of flood area	Flood Prone Land, Flood Planning, Flood Planning Land, Flood Planning Area, Development Control Map, Flood Planning Map, Flood
SA Proportion of Land with Flooding Susceptibility [3]	SA	Flood	Flooding		A (Negligible), X (Not applicable)	B (1-10% land susceptible to flooding)	C (10-30% land susceptible to flooding)	D (30-60% land susceptible to flooding), E (more than 60% land susceptible to flooding)
1% Annual Exceedance Probability for areas including Hobart, New Town and Sandy Bay rivulets and minor drainage lines [4]	TAS	Flood	Category			Within 1km of flood area	Within 500m of flood area	Flood-prone areas
VIC 1 in 100 Year Flood Extent Model [5]	VIC	Flood	Average Recurrence Interval			Within 1km of flood area	Within 500m of flood area	100
QLD 2015 flood mapping series [6]	QLD	Flood	Flood Type or Town Event			0.2% AEP	0.5% AEP	1% AEP, 2% AEP, 5% AEP, 10% AEP, 100 year
ACT 1 in 100 Year Flood Model [7]	ACT	Flood	Major Flood Event Area ID			Within 1km of flood area	Within 500m of flood area	Flood Area (denoted in the data as 1)
Alice Springs Flood Investigation and Floodplain Mapping Study [8]	NT	Flood	Annual Exceedance Probability			Within 1km of flood area	Within 500m of flood area	100 Year
WA DPIRD Soil Landscape Land Quality - Flood Risk [9]	WA	Flood	Flood Hazard Risk			L1, L2	M1, M2	H1, H2
2016 State of the Environment Land National Fire Return Frequency for Australia 1988 - 2015 [10]	All Australia	Bushfire	Number of times burnt	Allows some national consistency	0	1 to 9	10 to 19	20 to 28

Data Sources

[1] https://data.csiro.au/collection/csiro:12860
[2] https://www.planningportal.nsw.gov.au/opendata/dataset/epi-flood
[3] https://data.sa.gov.au/data/dataset/flooding/resource/ae844ded-5e66-413e-948d-dcffdbdb98a9
[4] https://data-1-hobartcc.opendata.arcgis.com/datasets/hobartcc::c12-0-flood-prone-hazard-areas-code-2/about
[5] https://discover.data.vic.gov.au/dataset/1-in-100-year-flood-extent
[6] https://www.data.qld.gov.au/dataset/queensland-flood-mapping-program-2015-series
[7] https://actmapi-actgov.opendata.arcgis.com/datasets/ACTGOV::flood-extent-1-in-100-year-flood-model-1-aep/explore?location=-35.520131%2C149.079911%2C10.43
[8] https://data.nt.gov.au/dataset/alice-springs-flood-investigation-and-floodplain-mapping-study
[9] https://data.gov.au/dataset/ds-wa-3bb606ab-4222-4df5-bd52-e8212a2a1ccd/details?q=flood
[10] https://data.gov.au/dataset/ds-dga-491fa8ce-5add-4d07-ba35-b7a8bd1d2c4d/details

Additional Hazard Categories Exposure Matrix & Data Sources

Dataset	State/s	Hazard Category	Field	Rationale	0 (Not Applicable)	1 (Low)	2 (Med)	3 (High)
Average Days Per Year Above 35C 1986-2005 [11]	All Australia	Extreme Heat	Average count days > 35C threshold [days per year]	Consistent national dataset. 35°C is defined by BoM as a 'hot day'. Track bucking or heat-related malfunctions unlikely below this temp.		0 to 5 days	Between 5 and 30 days	Greater than 30 days
Geoscience Australia 10% in 50 year seismic hazard map [13]	All Australia	Seismicity (Earthquake)	Peak Ground Acceleration Levels	Consistent national dataset		0.005 to 0.03	0.03 to 0.05	0.05 to 0.16
Global Landslide Hazard Map [14]	All Australia	Landslide	Landslide hazard	Consistent national dataset	Very Low	Low	Medium	High
Harmonised National Roadworks (21 June 2019 to 10 June and 21 September 2020 to present) [15]	All Australia	Road Hazards	Roadwork/ closure type	Consistent national dataset	N/A	N/A	N/A	Segment has experienced flooding or water over road previously (this supersedes the exposure score from any other flood dataset used)

Data Sources

[11], [12] https://www.climatechangeinaustralia.gov.au/en/projects/esci/esci-climate-data/?datatype=gridded&timespan1=1986-2005&results=true&variable1=maxtas&season1=annual&format1=nc
[13] https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/123132
[14] https://www.geonode-gfdrrlab.org/layers/hazard:ls_arup
[15] https://data.datahub.freightaustralia.gov.au/en_AU/dataset/harmonised-national-roadworks

Key limitations:

- Inconsistency in how flood data has been collected, processed and interpreted across states and territories – some significant gaps exist in NT and TAS.
- Other relevant factors such as flood depth and velocity are not considered due to lack of consistent data.
- Assessment does not take into account the potential effects of climate change, which may already be having an influence in some catchments.
- A global dataset is used for landslide hazard to allow for consistent analysis at a national scale, as opposed to combining different local assessments with different methods. However, this is likely to result in underestimation of the number and extent of supply chain linkages potentially affected by this hazard.

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