Transport for NSW

Asset Resilience Framework

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Document Control

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Change History

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1st Edition	Endorsed by the Asset Management Steering Committee	November 2023

Review

To provide continuous improvement this document should be reviewed at least on an annual basis or after any significant business process changes.

Preface

Resilience has emerged as an important focus for our customers and communities. A resilient and reliable transport system supports freight and passenger journeys and successful places. Transport networks contribute to the overall resilience of our places and communities.

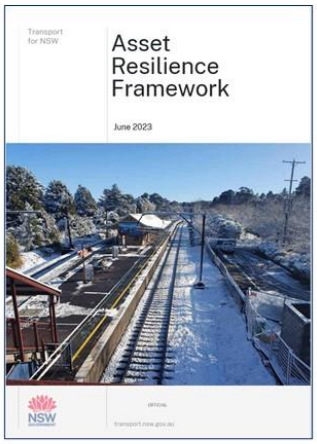
Transport for NSW (TfNSW) will meet the challenges of climate change, human-induced threats and economic uncertainty head-on by building resilience into our systems. We have begun to transition our transport fleet to net zero and we will support the roll out of electric vehicles across NSW.

TfNSW will identify risks and create new physical and digital pathways to keep people safe, moving and informed in the event of disruption. We will 'build back better' after extreme weather events, reduce waste, and ensure transport infrastructure makes a positive contribution to places and the environment.

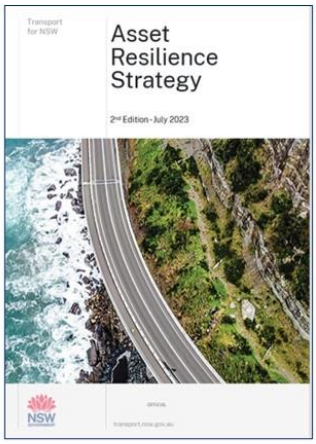
Our focus is on ensuring resilient journeys, communities and infrastructure that can withstand future shocks and stresses.

When damaging events occur, we need to reduce the risk and impact on communities and build back to a more resilient standard. Affected assets being renewed or replaced need to be designed to withstand the pressure they may be exposed to over their life, and the changing role they may play in making the entire system more resilient.

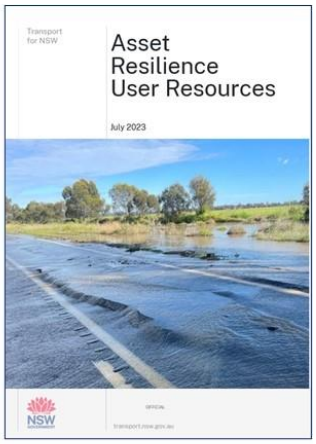
Many transport assets have long life cycles and need to be resilient to withstand shocks and stresses that compromise cost, risk and performance. Supporting a structured and systematic approach to asset resilience TfNSW have developed the following suite of artefacts:



Providing a consistent whole of life cycle approach to asset resilience



Strategic directions and responses that support a resilient transport system



Details current resources to support improved resilience outcomes

These artefacts focus on the resilience of the transport system. Proactive preparedness and resilience requires a whole-of system approach that considers both the resilience of individual assets and the contribution of these assets to the resilience of the overall system.

The NSW Reconstruction Authority is an agency within the Department of Planning and Environment which is responsible for facilitating disaster prevention, preparedness, recovery, reconstruction, and adaptation to the effects of natural disasters in NSW. TfNSW works closely with the NSW Reconstruction Authority to ensure consistency across government.

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1 Introduction

1.1 Purpose

The Asset Resilience Framework outlines a set of integrated elements that work together to provide Transport for NSW (TfNSW) with assurance that the intended network safety, infrastructure integrity, network availability and reliability outcomes are achieved.

Asset resilience is the resilience planned for, designed and built into assets, networks and systems[1].

Resilience is the adaptive capacity of an organisation in a complex and changing environment

Source: AS 5334-2013

The Asset Resilience Framework is designed to provide a consistent, whole of life cycle approach to asset resilience. Implementation of this Framework will improve transport network asset resilience and assure asset and service safety, security, availability, reliability and performance.

1.2 Scope

Organisational resilience incorporates many categories of resilience such as asset, human, financial and supply chain. Related management areas are shown in Figure 1 and all of these consider, analyse, and support delivery of improved resilience outcomes.

Figure 1: Organisational resilience and related management areas

The Asset Resilience Framework applies to asset resilience which is planned for, designed, and built into assets, networks and systems which are directly related to the transport network delivering passenger and freight transport services and operations.

The scope of the Asset Resilience Framework excludes assets not directly related to passenger and freight transport services and operations, such as corporate

[1] NSW Critical Infrastructure Resilience Strategy 2018 (Office of Emergency Management)

offices and IT assets. It does however recognise some interdependencies and interfaces with these assets that may need asset resilience consideration.

There are also interdependencies with organisational and community resilience which are outside the scope of this Framework.

1.3 Principles

The key principles which serve as the foundation for improved asset resilience across the transport network are outlined in Table 1.

Table 1: Key principles

	**Whole of life cycle and system** Delivering the desired balance of cost, risk and performance outcomes across the life of the asset together with the contribution of the asset to the resilience of the overall system
	**Informed decision making** Timely, accurate, relevant and governed information is used to inform asset management risk analysis and resilience decision making
	**Risk-based management** Risk management processes are used to identify, analyse, evaluate, prioritise and treat risks and evaluate responses
	**Alignment** There is a consistent transport wide approach with alignment to broader NSW Government outcomes
	**Innovation and improvement** Continuous improvement is delivered through intelligent, outcomes-based compliance
	**Build back better** Not only restore assets and services to normal, but to further strengthen those assets and services against future events of increasing likelihood and severity

1.4 Key stakeholders

The Asset Resilience Framework provides stakeholders with a level of assurance that the responses to asset resilience directions in the Asset Resilience Strategy will be achieved.

Table 2 identifies the key TfNSW asset resilience stakeholders with an interest in the Framework.

Table 2: Key TfNSW stakeholders

Stakeholder	Interest
Secretary of Transport	Transport portfolio oversight and assurance that asset resilience is incorporated into the transport network and services
Customer, Strategy & Technology	Development of future transport strategies to deliver resilient transport assets
Safety, Environment & Regulation	Establishes the framework, strategy and standards to implement asset resilience planning into asset management decision-making Provides risk-based assurance that the framework, strategy and standards are applied
Finance & Investment	Provides assurance that asset resilience is factored into economic analysis, business cases, investment decisions and benefit realisation & evaluation activities
Enterprise Governance & Assurance	Provides advice at an enterprise level on business continuity and resilience
Asset Custodians	Ensures that their assets, as part of the broader transport network, are resilient against natural hazards and human-induced risks taking into consideration whole of life cycle outcomes
Asset Stewards	Ensures the resilience of their services in delivering, operating or maintaining transport assets
Client	For capital project delivery ensures the resilience of the outcomes and that it meets the customer needs

In addition to TfNSW stakeholders, there are many external stakeholders that have an interest in the Framework. A sample of the key external stakeholders and their interest is provided in Table 3.

Table 3: Key external asset resilience stakeholders

Stakeholder	Interest
TAHE	Asset owner requires oversight and assurance that asset resilience is incorporated into the transport network
NSW Treasury	Treasury requires NSW government agencies to assess and predict all hazard risks to their assets and services and maintain whole-of-life asset resilience measures

Stakeholder	Interest
Infrastructure NSW (INSW)	In partnership with NSW Treasury, INSW form part of the gateway to fund NSW government agencies according to asset attestation and asset resilience requirements
Department of Planning and Environment (DPE)	The NSW Reconstruction Authority is an agency within DPE which is dedicated to disaster prevention, preparedness, recovery, and reconstruction
Local Government Authorities (LGAs)	Provide and maintain localised stormwater, sewage and potable water services that need to integrate to Transport drainage infrastructure A key contractor to TfNSW for the maintenance of state roads Maintain local and regional roads and the local level prevention and preparation activity for 'risk events' LGAs often have their own asset resilience strategies
Various emergency and enforcement services	For example: Fire and Rescue NSW, NSW Rural Fire Service, State Emergency Services, NSW Police Force Improved asset resilience contributes to the planning, assessing and responding to threats and events by this group of stakeholders
Transport customers and the NSW community	Confidence that Transport has a system which provides a consistent, whole of life cycle approach to asset resilience
National Emergency Management Agency (NEMA)	Manages the Disaster Ready Fund (DRF) for natural disaster resilience and risk reduction across Australia

2 Context and alignment

2.1 Organisational context

The role of TfNSW is to lead the development of a safe, efficient, integrated transport system.

Resilience is an important focus area for our customers and communities. A resilient and reliable transport system supports freight and passenger journeys and successful places. Transport networks contribute to the overall resilience of our places and communities.

Under the NSW Treasury Asset Management Policy (TPP 19-07), TfNSW is required to assess the resilience and vulnerability of our assets to the impacts of climate change, natural disasters and human-induced threats. We are guided to develop a 'system-of-systems' approach across interconnected infrastructure networks. This drives an integrated vision of infrastructure provision and management to create value, reduce costs, manage risks and improve the resilience of assets.

2.2 Asset management framework

The Transport Asset Management Framework (AMF) outlines a set of connected and related tools and includes policies, plans, strategies and business processes. The AMF provides TfNSW with assurance that asset management activities will deliver an integrated, modern transport system that puts the customer at the centre.

The AMF is the business approach for translating the organisation's objectives into risk-based sustainable asset and non-asset solutions. The AMF provides a structure to direct, coordinate and control asset management activities relating to the balancing of cost, risk and performance in order to deliver the desired outcomes.

The Asset Resilience Framework is a key support element within the AMF and outlines the integrated elements that work together to provide assurance that the required asset resilience outcomes are achieved.

The Asset Resilience Strategy identifies resilience actions which informs development of the organisational plans and objectives, together with the Strategic Asset and Services Plan (Strategic Plan (SASP)) and Asset and Services Plan (ASP). These relationships are shown in Figure 2.

Asset resilience is a core requirement in the Asset Custodian (divisional) Strategic Plan (SASP) and ASPs, together with modal ASPs. Asset resilience threats should be identified, assessed and quantified and mitigations should be identified and prioritised in the ASP.

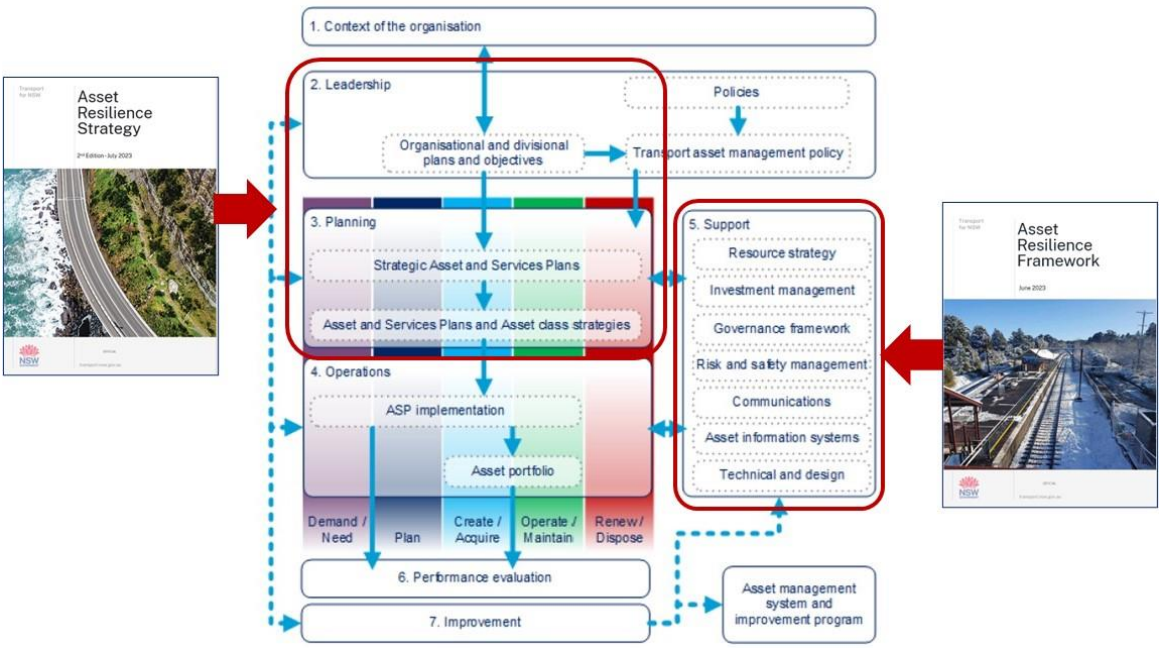

Figure 2: Alignment to the Asset Management Framework

2.3 Accountability roles

The AMF defines key roles to describe how it fulfils accountability in relation to its assets. The asset resilience accountability roles are consistent with those defined in the AMF and are described in Table 4.

Table 4: Asset resilience accountability roles

Role	Description
Asset owner	Owns the asset – this is generally either TfNSW or TAHE
Standard setter	Accountable for setting standards for assets (products and services) and establishing related assurance frameworks
Asset Custodian	Accountable for the end-to-end life cycle management and performance of assets (including asset condition, risk and reporting) on behalf of the asset owner to achieve agreed customer and community outcomes
Asset Steward	Accountable for the management and performance of assets (including asset condition, risk and reporting) on behalf of the Asset Custodian for the required life cycle stage and duration of the partner relationship (e.g. contracted operators and maintainers)

2.4 Governance oversight

The governance model used across asset resilience integrates into the formal TfNSW governance model for asset management frameworks, systems, processes and standards. This creates alignment between asset resilience and overall asset management, together with direct line of sight to the Executive.

The purpose of the Asset Management Steering Committee (AMSC) is to drive maturity, capability and consistent application of asset management practices across Transport. The AMSC is supported by the Asset Resilience Working Group (ARWG) which focuses on asset resilience practices across the asset life cycle.

The Finance, Investment & Assurance Committee (FIAC) supports sound financial governance by overseeing financial direction, allocation and controls which are aligned with the corporate strategy.

A key element of asset resilience governance oversight is delivered through the Strategic Plan (SASP) and ASP development and attestation processes as shown in Figure 3: Strategic Plan (SASP) and ASP governance oversight.

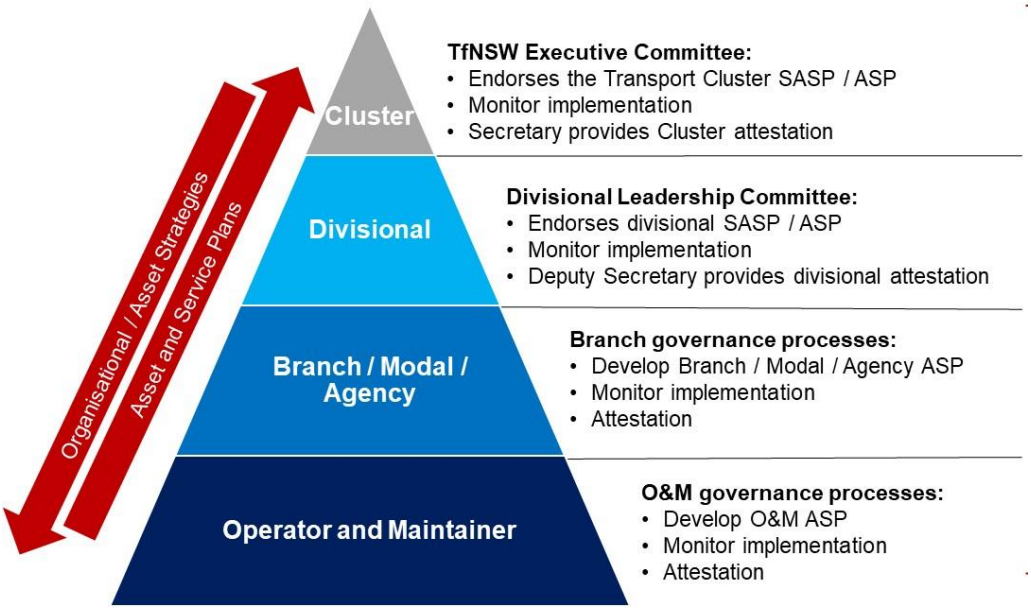

Figure 3: Strategic Plan (SASP) and ASP governance oversight

Organisational strategies and objectives, including the Asset Resilience Strategy, are driven top down from the cluster level to the asset operator and maintainer.

The ASP outlines the funding requirements, together with the risk and performance outcomes, to build operate and maintain the transport system in alignment with the organisational strategies and objectives. Attestation of the ASP at each level provides confidence and assurance of effective governance oversight.

3 Asset resilience planning and operation

Asset resilience planning and operation is based on a whole of life cycle total cost (totex) approach (Figure 4) that delivers fit for purpose, sustainable and reliable assets with clear visibility on all associated risks, costs and customer outcomes.

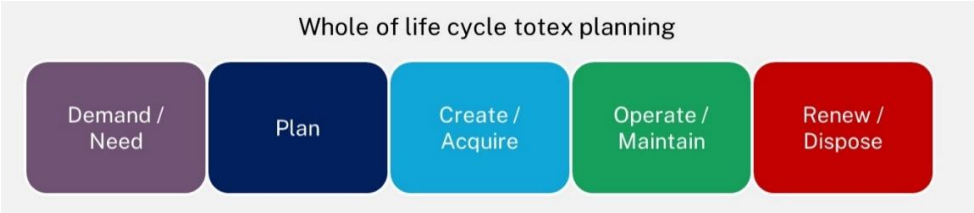

Figure 4: Life cycle Totex Planning

3.1 Planning

Asset resilience planning is embedded in Strategic Plan (SASPs) and ASPs to provide more detail specific to the asset portfolios, service performance measures, resilience actions, timescales, deliverables, budget, resources, and accountabilities.

Implementation of specific asset resilience actions is described in divisional ASPs and Strategic Plan (SASPs) as part of good asset management practice. Resilience threats and risks are identified, assessed, quantified, mitigations identified, and prioritised, and appropriate whole of life cycle asset resilience mitigations identified.

Asset Custodians and Asset Stewards identify activities, resources, and timescales to achieve the targets in the ASP. Where there are gaps, risks and mitigations must be included in the ASP process.

3.2 Deployment

The principles, objectives and recommended actions of the Asset Resilience Strategy are deployed to Asset Custodian and Asset Steward Strategic Plan (SASPs) and ASPs at a strategic, tactical, and operational level.

At a strategic level, future predicted natural hazard and human-induced risks and associated asset resilience actions are considered and embedded as an integral part of any service planning and investment. They form a key part of the strategic business case for any future transport capital investment in operational assets.

At a tactical level, proactive planning and execution of resilience actions is carried out on existing transport assets. The intent is to strengthen the resilience of existing assets that are identified as being most at risk of exposure to predicted upward trends in natural hazard and human-induced risks.

At an operational level, reactive actions are taken to respond to natural hazard and human-induced risk events to existing operational assets.

The relevant divisional Asset Custodians and Asset Stewards will execute the planned asset resilience actions according to their respective Strategic Plan (SASPs) and ASPs.

Divisions and agencies, in collaboration across TfNSW, will monitor and review the effectiveness of their asset resilience actions on an annual basis via their internal assurance processes. Their Strategic Plan (SASPs) and ASPs undergo annual reviews and continuous improvement actions are identified.

The resultant outcome of monitoring and reviewing of the resilience effectiveness will drive revisions and continuous improvement to asset resilience actions in future iterations of the Strategic Plan (SASPs) and ASPs.

3.3 Evidence-based decisions

TfNSW has key standard requirements for project delivery and business case preparation. There is a requirement for business cases to inform evidence and outcomes-based expenditure decisions that are in the public interest and demonstrate value for money.

All TfNSW initiatives are required to have a fit-for-purpose business case, and benefits realisation and evaluation artefacts which align to NSW Government policies and TfNSW guidelines. This provides the evidentiary basis of the plan forward and on a risk-based approach assesses the process, outcome and benefits realised.

The Business Case Advisory and Economic Advisory teams within the Finance and Investment Division (FID) have constructed a comprehensive Business Case Guide, Cost Benefit Analysis Guide and Benefit Realisation & Evaluation Guide for divisions across TfNSW to embed in their project delivery.

Table 5 identifies some of the areas where resilience is considered in business case decision-making.

Table 5: Resilience in business case decision-making

Guide	How resilience is addressed
Case for change	Asset resilience is assessed against existing and future risks, threats and adversities to understand the business need
Options development	Assess the risk to sustainability and resilience of the community for the long list of options prior to selection of short list of options
Value for money	Consider and develop 'Base Case' operating and maintenance costs in the context of step change events like 2020 bushfires or 2022 floods
Management analysis	Embed asset resilience analysis, outcomes and planning in the asset ownership and management plan

Asset resilience service offerings from the Economic Advisory team include:

- Advice and guidance on estimating economic benefits from prevention and mitigation of flood, bushfire, major transport incidents and other natural hazards in transport project business case and economic appraisal
- Well established flood immunity benefit methodologies for road and rail projects that can be used in project level analysis
- Working with stakeholders to develop carbon values and other climate change parameters to address long-term climate change issues
- Working with stakeholders to develop a 'base case' carbon measurement and valuation system for embodied carbon in construction and emissions in transport operation

Project teams throughout TfNSW use the Business Case Guide and the Business Case template that is aligned to NSW Treasury, INSW and Infrastructure Australia guidance for consistency.

Investment Logic Mapping is a mandatory requirement for Tier 1 – 4 projects and programs and asset resilience should be considered in this exercise to enable future benefit realisation and evaluation activities.

Estimates for whole of life costs to be included in the business cases must be derived in consultation with the Asset Custodians and Asset Stewards, as appropriate.

Funding proposals and their associated business cases go through a combination of internal and external assurance processes in accordance with the INSW Guidelines. Financial assurance is overseen by FID.

3.4 Climate change adaptation

In the coming decades, Australia will experience ongoing changes to its weather and climate. Australia is projected to experience:

- Continued increase in air temperatures, more heat extremes and fewer cold extremes.
- Continued decrease, on average, in cool season rainfall across many regions of southern and eastern Australia, which will likely lead to more time in drought, but with ongoing climate variability that will give rise to short-duration heavy-rainfall events at a range of timescales.
- Continued increase in the number of dangerous fire weather days and a longer fire season for southern and eastern Australia.
- Further sea level rise and continued warming and acidification of the oceans around Australia.
- Fewer tropical cyclones, but a greater proportion is projected to be of high intensity, with large variations from year to year.
- Reduced average snow depth in alpine regions, but with variations from year to year.[2]

The impacts of climate change will vary in their nature and level of risk from one part of the transport network to another. Recognising this variation and the need for tailor-made adaptation solutions, a flexible approach is required.

Adaptation planning should be based on risk management, where each case is considered in terms of the risks involved and the specific asset, its location and use.

The nature and extent of adaptation in each situation will depend on the costs and efforts involved compared with the benefits of adopting different adaptation strategies. Adaptation strategies could include:

1. Approaches to design standards or approvals;
2. Alteration, relocation or replacement of existing assets
3. Changes to operations or maintenance regimes.

[2] State of the Climate 2022: State of the Climate 2022: Bureau of Meteorology (bom.gov.au)

Importantly, climate change adaptation should be considered as part of whole of life, total cost asset management decision making processes. Table 6 outlines key climate change variables that should be considered in the decision-making process.

Table 6: Key climate change variables[3]

Element	Climate change variables (indicative)
Sea	Sea level rise Storm surge and storm tide Surface temperature Currents and waves Atmospheric salt
Rainfall	Average annual rainfall Extreme rainfall events Drought
Temperature	Average annual temperature Extreme temperature
Wind	Gales and extreme wind events Storms Cyclones Prevailing wind direction
Relative humidity	Average annual
Soil	Moisture Saltwater intrusion Salinity Runoff Ground stability Groundwater level
pH	Soil Fresh water Marine and estuarine
Bush fire risk	Fire danger index
Fog	Intensity, frequency and duration
Solar radiation	Temperature Cloud cover
Snow	Snow cover and snow line
Hail	Hail size and location
Lightning	Frequency and location of strikes
Evapotranspiration	Evaporation rates

[3] Australian Standard AS 5334-2013 – Climate change adaptation for settlements and infrastructure – A risk based approach

3.5 Risk management

The risk management structure for TfNSW is based on the principles and guidelines described in ISO 31000:2018 Risk Management and is detailed in the Transport Enterprise Risk Management (TERM) Standard.

Asset resilience risks are required to be identified and managed in accordance with the TERM. TERM provides the strategy, architecture, process and protocols for managing all risks within TfNSW.

Risk management processes are used to identify and rate risks based on likelihood and consequence rankings described in the TERM standard. We then use this risk information to underpin our decision-making processes to mitigate risks.

Asset resilience risk identification and management is informed by Asset Custodians and Asset Stewards through the asset management process and funding.

The organisational level asset resilience risks are informed through the divisional and modal ASPs and then articulated in the cluster ASP with corresponding mitigation controls.

4 Resilient systems approach

A forward looking resilience approach involves identifying potential future hazards and developing adaption measures to reduce the risks to assets.

Not all hazards are identified, nor is adaption always feasible. The systems approach involves detecting, responding, recovering from and adapting to a natural or human-induced risk trigger.

This sequence identifies actions that TfNSW can take to control or eliminate the causes or adverse precursor conditions and reduce consequential loss or harm and is illustrated in Figure 5 and further explained in sections 4.1 to 4.4.

Figure 5: Asset and service states due to a risk event

4.1 Detect

Normal Mode operation

The approach commences with assets and services operating in 'normal mode,' for example managing assets to meet the needs of the network under average conditions and usage within available budget. Essential to the process is identification of the assets.

Identify potential future hazards / risks

The Asset Custodian and Asset Steward identify and assess the exposure of existing operational transport assets to future and emerging trends in natural hazard (i.e. climate change) or human-induced (i.e. cyber, terrorism) risk events. This is done using a range of risk prediction tools, methods and models in collaboration with key stakeholders to ensure a holistic system assessment.

Tactical adaptation to reduce future risk

Asset Custodians, Asset Stewards and subject matter experts use risk identification and analysis to plan and carry out pro-active tactical adaptation (including climate change adaptation) and upgrades to existing at-risk operational transport assets, or plan and acquire new resilient replacement assets.

Tactical adaptation will be more successful if assets are identified and mapped.

Adverse precursor conditions emerge

Transport assets are exposed to a range of adverse precursor conditions for natural hazards that are likely to occur with increasingly destructive impacts due to climate change effects.

For example, natural hazard precursor conditions for a bushfire event may develop, such as high vegetation fuel load, and protracted hot, dry, windy weather. Asset resilience actions at this stage include vegetation fuel load surveys, adverse weather condition monitoring, planned vegetation removal and hazard reduction burns.

Detection and provide early warning of adverse precursor conditions

To predict natural hazards progressing to an event, we require early warning techniques, sensors and systems that can detect the potential threat of hazards escalating to a risk event.

Asset resilience actions for a bushfire event at this stage could include detection methods such as vegetation and tree canopy fuel-load surveys utilising aerial drone or satellite surveillance, sensors for temperature, humidity and wind, and RFS fire alerts. Using satellite imagery with machine vision and artificial intelligence can aid with accurate and timely early detection, analysis and warning and decision-support.

4.2 Respond

Event trigger

A hazard needs a trigger or other initiating event to progress to an actual risk event. The trigger for the bushfire risk event is ignition, which could be via natural or human causes.

Risk Event (assets damaged / destroyed)

Once the hazardous event occurs, it will destroy, adversely affect, or disrupt transport or third-party dependency assets, operational capabilities, and services.

Emergency Mode operation (service disrupted)

As a result of the hazardous event and service disruption, the transport system transitions to ‘emergency mode’ operation, which could involve shutting down services for protracted periods.

Assess operational or service impact

At this point TfNSW will assess the asset loss and operational impact from a range of perspectives, including safety, security, service availability and maintainability.

Deploy Emergency Response

TfNSW will then select and invoke appropriate prepared emergency response and business continuity plans and carry out the operational responses. In the bushfire case, this would include firefighting, transport service diversion, rerouting and other operational changes.

4.3 Recover

Degraded Mode operation (service still disrupted)

If the immediate emergency response is successful, like a bushfire being extinguished and people safely evacuated; this may lead to a partial service recovery or a 'degraded mode' state of operation. Some emergency repairs may be carried out to lift performance levels from emergency mode to degraded mode operations.

Tactical Repair and Service Restoration

Once safe to do so, maintenance teams respond with tactical repairs to repair and replace damaged infrastructure and to return assets and services to the 'normal mode' state of operation. Asset resilience actions as part of iterative learning include reviewing performance and refining emergency response plans, processes, resources, and competencies.

Normal Mode (post-event)

All actions to this point are tactical responses to return infrastructure assets and services to the "business-as-usual" normal mode status before the event.

4.4 Adapt

Post-Event Analysis (lessons learned for adaptation)

TfNSW as a continuously improving organisation needs to analyse and adapt responses to emerging and extreme hazardous events. This includes analysing causes and impacts for each event, the damages and losses, and to refine and improve responses to these events.

Asset resilience actions at this stage involve identifying adverse precursor conditions, which assets were damaged, the nature of the damage, and the properties of the assets that made them susceptible to damage, e.g., timber poles for HV aerial feeders destroyed by the bushfires.

Plan Strategic Asset Resilience Upgrades

TfNSW will then need to develop and evolve asset resilience and adaptation to plan and upgrade assets to be more resilient to these increasingly likely extreme events such as bushfires and floods.

Implement Strategic Asset Resilience Upgrades

The result will then be to implement these actions to increase resilience of existing assets, or to acquire and sustain newer, inherently resilient future assets.

For example, in bushfire prone areas, replacing HV aerial feeder timber poles with concrete poles, burying the feeders, diverting the feeders around high bushfire risk areas, or maintaining vegetation clearances adjacent to poles.

A Better Normal. A more resilient future

The long-term strategic outcome will be more resilient assets and services that have evolved and adapted to future predicted environmental conditions.

5 Resilience actions

Resilience actions can be broadly categorised as predictive actions to avoid the threat and reactive actions to recover from an event.

5.1 Predictive actions

Examples of predictive actions shown in Figure 6 are discussed in further detail below.

Figure 6: Examples of predictive actions

Prediction of future threats, risks or adversities

This can be achieved by modelling and prediction software tools and Software as a Service (SaaS) services offered by government and private sector entities.

Asset or system redesign

Involves evaluating emerging risks to particular assets and proactively re-designing those assets and systems to be more resilient to those future risks.

Emergency planning

Involves reviewing the existing suite of emergency plans based on historical events and the success or failure of the emergency response to those events. Additionally, reviewing future events based on the predicted risks, threats and adversities of increasing likelihood and severity.

Threat detection / early warning

Threat detection may involve planning, developing and implementing early warning systems and the associated sensor networks. The intent being to provide proactive and accurate warning of emerging adverse precursor conditions (vegetation fuel load, high temperatures, high winds, and low humidity) prior to a risk event such as a bushfire, flood or landslide.

5.2 Reactive actions

Examples of reactive actions shown in Figure 7 are discussed in further detail below.

Figure 7: Examples of reactive actions

Emergency response

As a resilience action, emergency response could involve reviewing existing emergency response drills, and carrying out enhanced training and practice drills. These ensure that operators, emergency response staff and maintainers are 'match fit' for future predicted risk event scenarios.

Emergency repairs

Reviewing emergency maintenance and repair responses to historical events, and improving maintainer training, processes, tools, plant and other equipment. This will enable a more effective response to future predicted risk events to return systems to normal mode operation as rapidly and efficiently as possible.

Long-term repairs

Typically involves replacing the emergency repairs including temporary structures, temporary power supplies or pothole repairs with permanent repairs such as new structures, permanent and more resilient power supplies, or regrading and resurfacing a road.

Lessons learned

Involves reviewing and analysing the loss and harm impacts of a risk event after the asset and services have been restored to normal mode. It synthesises new asset and system designs that adapt to the increasing risk environment, for example climate change adaptation.

Adaptation

Resilient assets and services that have evolved and adapted to future predicted environmental conditions.

6 Techniques and tools

Techniques and tools, such as clearly defined roles and responsibilities, documented processes, effective governance and collaboration across key stakeholders are fundamental to delivering improved resilience outcomes.

6.1 Resilience engineering techniques

This list of resilience engineering techniques that could be applied to TfNSW's existing and new assets and services is not comprehensive but represents examples of approaches that may be adopted (Figure 8).

Figure 8: Examples of resilience engineering techniques

Absorption involves designing assets that can absorb the impact of the risk event. For example, structures that can absorb the forces from cyclonic winds, structural foundations that can absorb shock and vibration forces from an earthquake, or surge protection systems that can absorb the energy from a lightning strike to protect electrical and electronic systems.

Redundancy is particularly useful in electrical, data and communication networks, where the loss of a link between two nodes can be compensated for by rapid automatic reconfiguration of network links via other nodes. This is the nature of the internet. While existing electrical and data communications networks are already designed with a defined level of redundancy, large-scale risk events triggered by climate change can result in redundant links being destroyed, and these may need redesign.

Redundancy is also built into critical operations facilities such as data and control centres and a consideration to the location of spare parts.

Human in the loop considers scenarios where a large risk event leads to a loss of automation functions, which requires reversion to human action and manual procedures and protocols. An example might be the loss of the signalling control system on a railway that requires reversion to manual processes and protocols whereby signallers use radio to authorise train drivers to proceed from signal to signal under verbal instruction and safe protocols.

Shielding provides protection between the physical threats from the operational environment and the assets and systems at risk. A shielding example would be a seawall or levee to protect coastal land transport corridors from storm surges or coastal inundation, or anti-throw screens on bridges.

Avoidance involves planning and design (or redesign) of transport assets including rail and road corridors to avoid future predicted risk events. For example in the strategic planning phase for a new rail or road corridor, an alignment is selected that considers predicted climate change effects for rainfall levels that may create future floodplains. This may drive decisions to divert a corridor by 100s or 1000s of metres from the original alignment to avoid the predicted floodplain.

Complexity avoidance seeks to reduce the complexity of a transport system where practicable on the basis that complex systems exhibit less predictable responses to a risk event. The simpler the system design, the easier it is to analyse its failure modes following a risk event and to restore normal mode operations.

Modularity in system design has many benefits in terms of cost, transportability, constructability, integration, testing, maintainability, and disposability at the end of its design life. Modularity also enables the Asset Steward to rapidly replace a damaged or destroyed element of infrastructure following a major risk event. While modularity has been common practice in electrical and electronic systems for decades, it is now becoming a feature of civil structures such as bridges and viaducts through modern methods of construction.

Defence in depth relates specifically to protection and resilience of technology systems from cyber-attack threats. It involves a layered defence architecture that protects the network from penetration, followed by protection of the host system (server farm), then the application (rail or road traffic management software), and finally the data itself.

6.2 Decision support models and tools

TfNSW uses prediction, analysis and decision-support resilience models and tools to prepare and plan for short-term tactical and long-term strategic asset resilience actions.

These models and tools link assets to geographic locations, which in turn relate to areas where natural hazard and human-induced risks are likely to affect transport assets and services.

Some available decision-support models, tools and services to assist in planning, identifying, reporting and managing resilience and risks are identified in Table 7.

Table 7: Asset resilience decision-support models and tools available to Transport

Tool or Service	Description
XDI Globe (DPE and XDI Systems)[4]	A climate change based natural hazard model based on a subscriber model established by DPE as a NSW government resource, that uses NARCliM climate change data models overlaid onto assets on a geospatial platform.

[4] Cross Dependency Initiative: XDI Globe. Last accessed 29 May 2023.

Tool or Service	Description
Climate Risk Assessment tool (TfNSW)[5]	Developed by the Environment and Sustainability Branch of SER to provide project and site-specific climate risk data for engineering decisions
Network Resilience Risk Register	Developed by Sydney Trains that identifies, links, and analyses a range of natural hazard and human-induced risks to rail asset classes and identifies strategies to increase resilience.
NSW Spatial Digital Twin[6]	Source of multiple NSW data sets, including transport assets and climate risks
BoM Tropical Cyclone Knowledge Centre[7]	Source of historical cyclone paths within effective distances from NSW and their long-term southward trend, as well as short-term forecasts.
Earthquakes@GA[8]	Earthquake and geological fault monitoring tool by Geoscience Australia. This service is available at https://earthquakes.ga.gov.au/
Live Traffic NSW	Live Traffic NSW provides near real-time updates on NSW road availability in terms of incidents such as crashes, breakdowns, general hazards, roadwork, changed traffic conditions, flood levels, and other environmental parameters. It is available at https://www.livetraffic.com
BoM Weather	BoM Weather by the Australian Bureau of Meteorology (BoM) is available as a downloadable smartphone app and is also available in a desktop version for NSW at http://www.bom.gov.au/nsw/?ref=hdr
Hazards Near Me	Hazards Near Me is available as a downloadable smartphone app to view emergency warnings and advice for fires, floods and tsunamis in NSW Hazards Near Me app | NSW Government

5 Transport for NSW; TfNSW Climate Risk Assessment Guidelines; 2021. Last accessed 29 May 2023.

6 NSW Spatial Digital Twin. Last accessed 29 May 2023.

7 Australian Government, Bureau of Meteorology: Tropical Cyclone Knowledge Centre. Last accessed 29 May 2023.

8 Australian Government, Geoscience Australia. Earthquakes@GA. Last accessed 29 May 2023.

Tool or Service	Description
Waze	Waze is a road navigation and information sharing platform from Google, where drivers can report incidents via the app, which is useful for emergency response planning and road user warnings of road hazards. It is available in desktop or mobile form, and is available at https://www.waze.com/live-map
Google Maps	Google Maps provides additional information overlaid on the basic mapping platform, including traffic congestion and hazard alerts that may arise from natural hazard or human-induced risk events such as bushfire, floods and accidents
TECCH Tools	Transport's Emergency and Crisis Coordination Hub (TECCH) is managed by the Security, Crisis and Emergency Management Operations Team within SER. The TECCH can support the needs of the business by utilising a range of tools including live asset tracking, geospatial analysis and hazard modelling.
FloodMapp	This tool is managed by the Security, Crisis and Emergency Management team in SER and provides detailed hydrological and hydraulics models using artificial intelligence and data streams
Natural Hazards: 10 years of incidents on the network (nsw.gov.au)	Transport (Environment and Sustainability) have a layer on GeoHub called 'Natural Hazards: 10-years of incidents on the network', which can overlay the cluster of incidents against projects and network to indicate resilience 'hotspots'.

7 Performance monitoring and improvement

Divisional and agency-level ASPs and Strategic Plan (SASPs) identify, monitor and report on the risks that affect the resilience of their specific assets and services.

Once divisions and agencies have established asset resilience actions in their ASPs and Strategic Plan (SASPs), they must monitor and report on their assets and services state-of-resilience. This includes vulnerability to existing, evolving and emerging natural hazard or human-induced risks.

7.1 Performance indicators

Any well-structured governance framework should have at its core a set of objective metrics or key performance indicators to measure the effectiveness of its actions and outcomes. This applies to measurement of the effectiveness of asset resilience actions and outcomes.

At a minimum the asset resilience performance metrics detailed in Table 8 are provided in the cluster and divisional ASPs, monitored and reported to Infrastructure NSW in accordance with the infrastructure performance data requirements.

Table 8: Minimum asset resilience performance metrics

Performance Element	Metric
Capital fiscal impact	Sum of capital impacts in the last financial year / asset written down value
Operating fiscal impact	Sum of operational or revenue impacts in the last financial year / total operation spend

The following questions are provided as guidance to support asset resilience performance analysis:

- What is the infrastructure system's capability to prevent, protect and recover against significant multi-hazard threats with minimum consequences for public safety, the economy and security?
- What is level of historic impact to assets (cost, performance, services) from natural hazard events?
- What is level of historic impact to assets (cost, performance, services) from human-induced threats (including pandemics) or events?
- Which critical and significant assets are most at risk from future resilience scenarios?

In addition to the above minimum performance metrics Table 9 includes examples of typical resilience metrics that can be used to assess the effectiveness of asset resilience.

Table 9: Typical resilience performance metrics

Performance Element	Metric
Cost to recover	Total cost to recover to full operating condition

Performance Element	Metric
Time duration of recovery	Time to restore to full operating condition
Performance before and after	Extent to which recovered operation degraded
Outage period	Time to recover to safe operation
Asset resilience plans	% of the network covered by a transport corridor resilience plan

7.2 Monitoring

Asset Custodians monitor and report progress in implementing their asset resilience actions in accordance with their ASPs, including but not necessarily limited to:

- Reviewing performance of asset resilience adaptation measures implemented. For example: How well did the measures introduced after the latest bushfire or flood event improve the resilience and availability of assets in future before the next bushfire or flood season?
- Reviewing success of the asset and service resilience interventions or adaptations.
- Monitoring tactical resilience adaptation actions implementation progress; for example, how many under road and rail culverts were cleared of debris or upsized in the past 6 months?
- Monitoring strategic resilience by building and adaptation actions and implementation progress; for example, how many timber poles were replaced with steel or concrete poles in the bushfire-prone areas, or how many HV aerial cables were moved underground in the past year?
- Monitoring resilience of the current networks. Regular assurance reviews and audits to identify asset performance during high impact events.

7.3 Innovation and improvement

The ARWG is responsible for facilitating the sharing of asset resilience data, knowledge and innovation and implementation of continuous improvement initiatives.

Key ARWG initiatives include:

- Developing, reviewing and enhancing asset resilience management artefacts
- Facilitating asset resilience related engagement, communications and issues management across Transport
- Sharing asset resilience actions, interventions and lessons learned across the asset life cycle – from incorporating resilience into asset planning and development through to responding to resilience risks and threats.

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