
Valuing resilience in infrastructure

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Acknowledgements

The project team acknowledge the valuable input from our Advisory Committee and Peer Reviewers:

- **NZ Transport Agency:** Sandy Fong, Stuart Woods
- **Ministry of Transport:** Ian Duncan
- **National Infrastructure Unit:** Roger Fairclough
- **Local Governments:** Russell Hawkes (Environment Southland), Mike Mendonca (Wellington City Council)
- **Peer Reviewers:** Erica Seville (Resilient Organisations), John Spiers (Arcadis)
- **Project Directors:** Chris Money (EY), Richard Reinen-Hamill (T+T)

Research need

- Resilience is a priority for transport
- Improving resilience is desirable
- Current assessment of resilience is subjective
 - What should we be resilient to?
 - Can resilience be valued?
 - How do we prioritise resilience improvements?



Objective & context

To develop a framework which supports the evaluation of different controls that aim to create an acceptable level of resilience in (transport) infrastructure – in the context of broader social, economic and environmental outcomes - as defined by stakeholders

Hutt Valley



Kaikoura



Tamaki Drive



NATIONAL DISASTER RESILIENCE STRATEGY: PRIORITIES

<p>Priority Area 1: Improve the understanding of risk to enable better risk-informed decision-making</p>	<p>Priority Area 2: Reduce existing risk and minimise the creation of new risk</p>	<p>Priority Area 3: Strengthen resilience, both planned and adaptive</p>	<p>Priority Area 4: Build a culture of resilience</p>
<p>Focus Area #1 Data Collection, Management and Availability (incl geospatial) for DRRR</p> <ul style="list-style-type: none"> Increased use of location-based info; risk mapping; geospatial policy National datasets, data standards Data sharing, data availability/accessibility, incl. real-time data Centralised national/local risk info portals National loss database <p>Focus Area #2 Improving our Risk Assessment Capability</p> <ul style="list-style-type: none"> Improved/standardised risk assessment methodology, incl improved asst of exposure and vulnerability Evaluation of multi-capital impacts (e.g. economic cost of social impacts) National risk assessment Identify high-hazard/high-risk communities Tools for improved risk modelling and forecasting, including system trends Support LGRA <p>Focus Area #3 Defining Risk Tolerance and Acceptability</p> <ul style="list-style-type: none"> Research/advice Guidance for risk tolerance/acceptable risk Orgs to define risk tolerance <p>Focus Area #4 Improving the Way we Communicate Risk for Improved Risk Literacy</p> <ul style="list-style-type: none"> Risk comms research into policy/practice Guidance on risk comms Updated hazardscape National risk conversation(s) <p>Focus Area #5 Tools and Resources to Enable Decision-making</p> <ul style="list-style-type: none"> Multi-capital decision making tools Case studies of cost-benefit of risk reduction as part of toolkit to persuade decision-makers Methods for quantifying and pricing risk 	<p>Focus Area #6 Asset Risk Management for Resilience</p> <ul style="list-style-type: none"> Resilience measures in council 30-year asset management plans Support the Built Environment Action Plan LGRA [??] <p>Focus Area #7 Tackling Retreat and Relocation</p> <ul style="list-style-type: none"> National policy Local policies Public/community conversations about <p>Focus Area #8 Integrating Climate Change Adaptation with Mainstream HRM</p> <ul style="list-style-type: none"> Support/implement Natural hazards NPS [??] [??] <p>Focus Area #9 (Incentivising) Resilient Development</p> <ul style="list-style-type: none"> Improving the District Plan process Other land-use planning improvements/ initiatives [??] Insurance incentives for resilience Target audiences: Developers, Planners, etc Resources for 'making resilience easy' <p>Focus Area #10 Risk Financing, Transfer and Insurance</p> <ul style="list-style-type: none"> Financial instruments for resilience Insurance products that support/encourage resilience National position on reinstatement Financial planning for long-term adaptation Guidance for local authorities on risk transfer strategies Other [??] 	<p>Focus Area #11 Individual and Household Resilience</p> <ul style="list-style-type: none"> Emphasis on the most vulnerable incl. low/no income earners Making risk reduction/resilience easy <p>Focus Areas #12 Business and Organisational Resilience</p> <ul style="list-style-type: none"> Promote the role of the private sector in resilience Make business continuity management simple Promote adaptive resilience practices Organisational resilience objectives in strategic plans Organisational risk/resilience objectives in job descriptions/performance agreements <p>Focus Area #13 Community Resilience</p> <ul style="list-style-type: none"> National/local coalitions for community resilience Community development practices Vulnerable people and groups Rural resilience advice/advisors Marae preparedness <p>Focus Area #14 City/District Resilience</p> <ul style="list-style-type: none"> Local authority resilience strategies City resilience framework/guidance Case studies Chief Resilience Officers <p>Focus Area #15 Readiness for Response</p> <ul style="list-style-type: none"> Public alerting Crowd sourcing and citizen science to inform response management <p>Focus Area #16 Readiness for Recovery</p> <ul style="list-style-type: none"> Strategic recovery planning Readiness for reconstruction 	<p>Focus Area #17 Governance and Leadership</p> <ul style="list-style-type: none"> Governance mechanism for this Strategy Review local and regional governance arrangements Engaging elected representatives Integrate learnings from resilience-related research platforms (NSC, QuakeCORE etc) Resilience objectives in local authority strategic plans Oversight of high-hazard/high-risk communities by local/regional/national governance bodies Networks for resilience Integrate the private sector into public sector governance arrangements for risk/resilience <p>Focus Area #18 Embracing our Diversity and Building our Cultural Capital</p> <ul style="list-style-type: none"> MCDEM to create a national kahui to provide input into resilience programmes and policy Resilience strategies should include indigenous knowledge/worldviews Civic education Nationhood Culture/heritage <p>Focus Area #19 New Technology for DRRR</p> <ul style="list-style-type: none"> Working group for future foresight; process to envt scan new innovations in DRRR Keeping in pace with social media and information needs <p>Focus area #20 Outreach and Education</p> <ul style="list-style-type: none"> Knowledge building of govt officials, civil society, communities, volunteers, private sector DRRR in school curriculum DRRR in vocational education Resilience advisors and other targeted, customer-focussed advice

NB. Each focus area will have a number of generic and specific actions aimed to triangulate to provide progress over the 10 year period

A consolidated definition

Resilience is the ability of systems (including infrastructure, government, business and communities) to proactively resist, absorb, recover from, or adapt to, disruption within a timeframe which is tolerable from a social, economic, cultural and environmental perspective

(adapted by project team for NZTA from USDHS 2009a in AECOM 2015)

Resilience is **not restricted** to natural hazards: resilience to organisational or systemic challenges is equally important

- Provide for a spectrum of stresses and shocks (the former is often under-estimated)

Confirmed **resist, absorb, recover, adapt** are the outcomes of resilience and form the basis for the taxonomy

Including **tolerance** allows the resilience of the system to be placed in the context of the communities value of the function of the system

Takes a **wide view** of value (which can be weighted if desired, and also allows the inclusion of wider economic benefits)

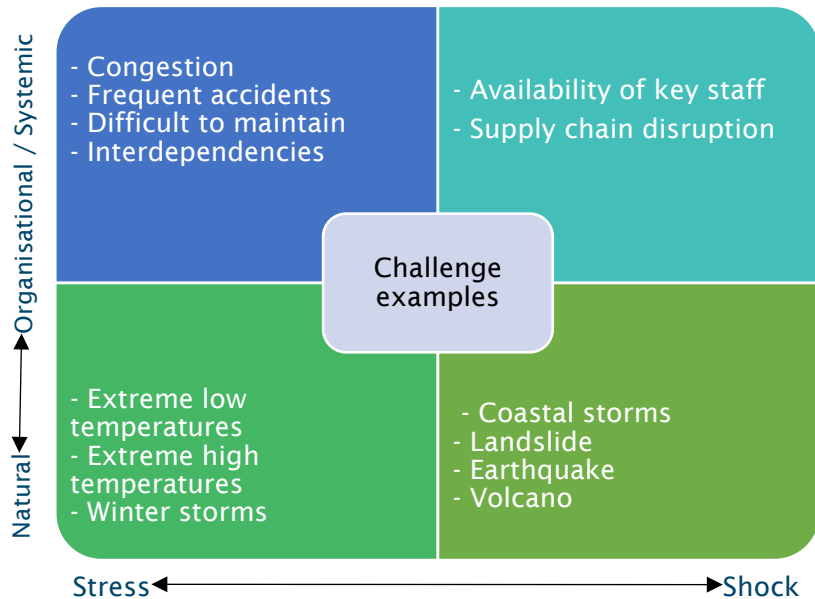
Focuses on **outcomes** of the system (e.g. level of service provided) versus *outputs or components* of the system

Resilience should be **proactively** sought as an outcome of decisioning

A consolidated taxonomy

An infinite number of scenarios could disrupt a transport network and an equally inordinate amount of controls are available to lower this risk

Challenges: the universe of challenges is large and includes four main dimensions (which work together to form a challenge matrix)



Controls are equally numerous, but can be transport-centric or non-transport. Overall controls fall into four main categories

Tool overview

Supports the evaluation of different controls that aim to create an acceptable level of resilience in (transport) infrastructure – in the context of broader social, economic and environmental outcomes - as defined by stakeholders

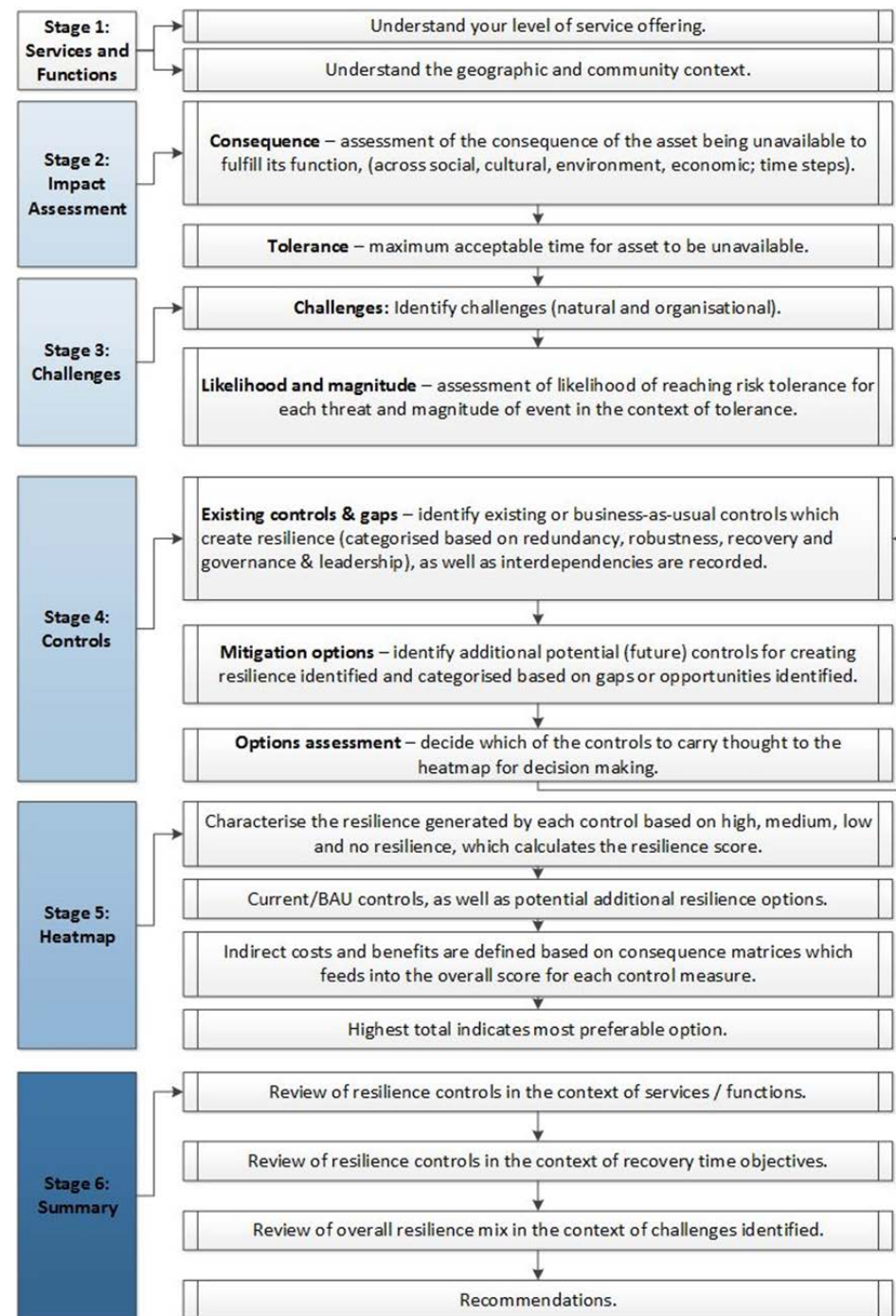
Practical: end-to-end solution for evaluating and responding to risk which can be integrated into existing (NZTA) processes

Leverages work undertaken to-date: explicitly allows for maturity / progression of approach (effort) over time

Outcomes focused: puts the function of assets within a system at the heart of decisioning and focuses on the consequences of assets not being available to users(i.e. not being resilient)

Community focused: allows for a range of stakeholder perspectives to be included in decisioning

Scalable: can be used in other sectors, system versus asset-specific, and can be used to compare investments across different regions



Decision support tool

Petone Esplanade & Waione Street Bridge Case Study



Context

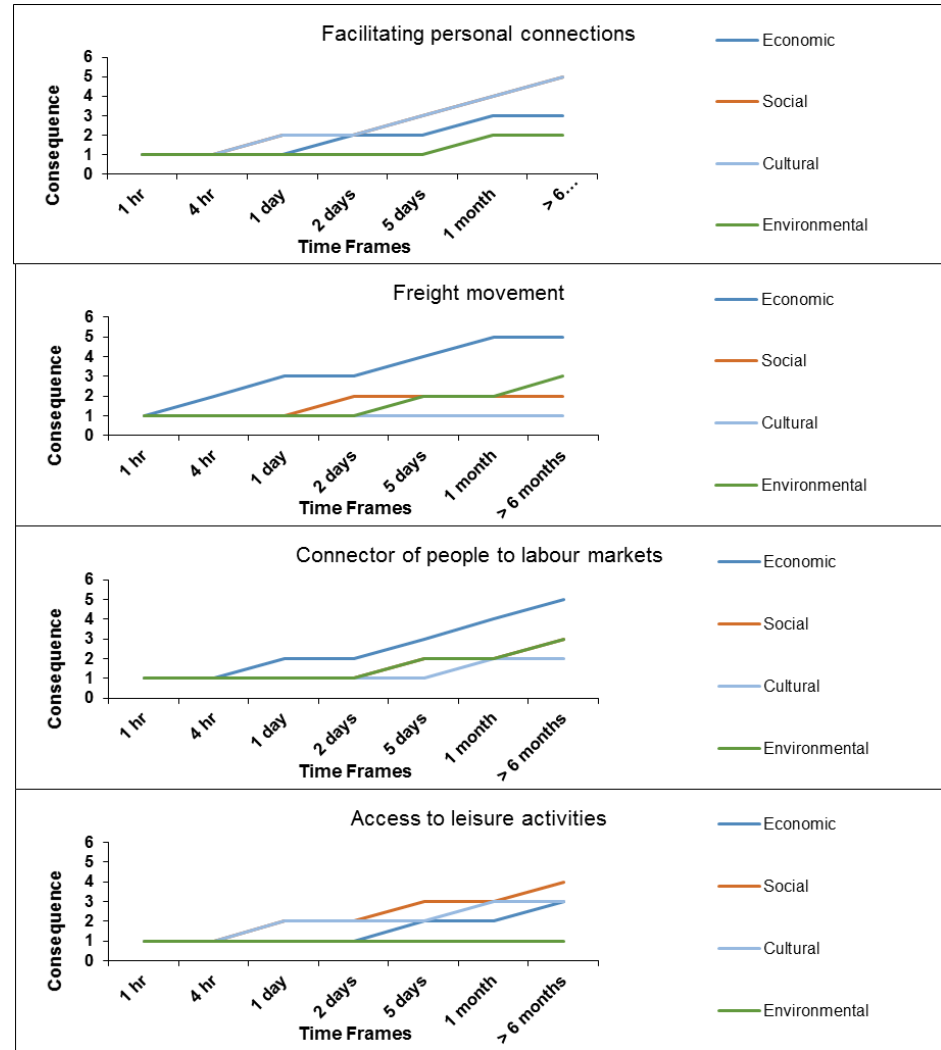
Petone Esplanade & Waione St Bridge

- **Critical Functions:**

- Facilitating personal connections
- Freight movement
- Connecting people to the labour markets
- Access to leisure activities

- **Overall Recovery Time Objective:** 24-hours at 50%

- **Key Challenges:** Winter Storms, Congestion, Flooding



Heatmap

30-Nov-16			Challenge	Challenge	Challenge	Challenge	Challenge	Challenge	Indirect Costs of Control				Indirect Benefits of Control				Total	Cost of control	Source
Control	Primary Characteristic		Flooding	Winter storms: snow, ice, hail	Congestion	Earthquake: liquefaction, tsunami, landslide, sinkholes	Landslide	Interdependencies with other assets (operation or maintenance)	Environment	Social	Cultural	Economic	Environment	Social	Cultural	Economic			
Current	Stop banks	Robustness through Civil Engineering	L	L	H	L	L	M	M	L	L	L	M	M	L	M	27	TBC	TBC
Current	Recovery contracts	Recovery through Processes	M	L	L	L	L	L	L	L	L	L	L	L	L	L	23	\$1m	Estimate
Current	Capacity improvements	Robustness through Civil Engineering	L	H	L	L	L	M	M	M	M	M	L	L	L	M	22	\$20-90m	SH2 Ngauranga - Te Marua PBC
Current	Recovery contracts	Recovery through Processes	L	L	L	M	M	L	L	L	L	L	L	L	L	L	24	\$3m	Estimate
Future	Communication around working	Governance through Information Technology	H	L	H	L	L	L	L	L	L	L	L	M	L	M	28	\$1m	Estimate
Future	Land use change	Governance through People	L	M	L	L	L	L	M	M	M	M	L	L	L	L	0	\$1m	Estimate
Future	Cross Valley Link	Redundancy through Civil Engineering	M	H	L	M	L	M	M	H	M	L	L	H	M	M	27	\$70m	CVL Strategic Case
Future	Barge Landing	Redundancy through Civil Engineering	M	L	L	M	M	M	H	L	M	L	L	L	L	M	0	\$100m	Estimate
			10	10	10	8	7	9											

Two new measures score the highest on the total resilience score

- Explore **communication tools** to encourage people to work from home during emergencies.

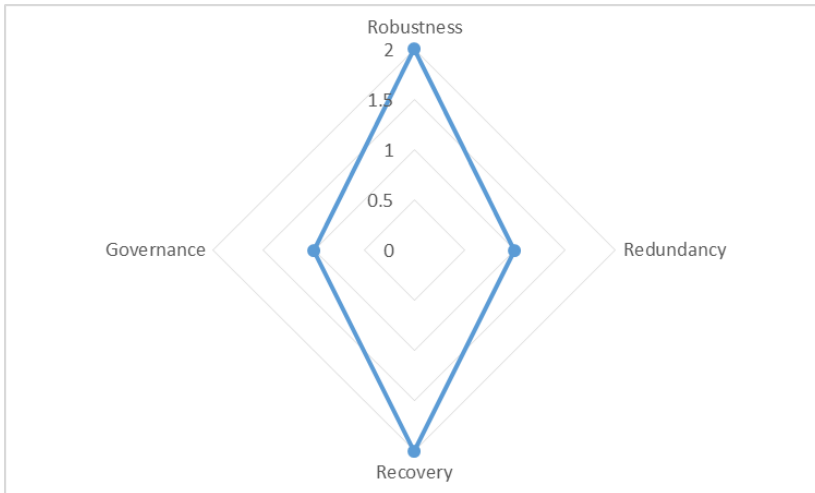
- Explore **CVL** further

Controls don't materially help mitigate against the challenges the asset is most exposed to

Other controls should be considered

- Further **recovery contracts**
- Higher cost options such as a **barge landing** require considerably more investigation if they are to be justified on resilience grounds alone

Controls recommended focus on **Robustness** and **Recovery** in particular



Next steps





Future Focus Areas

Test

- Opportunities to put research into practice: testing of tool under different scenarios and sensitivity assessment

Implement

- Implementation of tool and development of business rules for NZTA
- Opportunities to work with other asset class owners and organisations

Improve

- Data integration and automation
- Community engagement: ways of effectively engaging with communities to understand tolerance to outage and willingness to pay
- Better measurement of indirect costs and benefits: particularly considering the method to calculate travel time reliability (federal buffer zones)
- Network assessment: consider developing further to be used across a network

Appendix A

Definitions



Redundancy

Provision of functionally similar outcomes, to an acceptable standard, during lost or degraded levels of service

This definition includes important elements of:

Function: Decision makers need to be fully aware of the function (level of service) of the asset in question.

Outcomes: Decision makers should be aware of the outcomes they are trying to provide for – not just focusing on the provision of new assets.

Acceptable standards: Understanding the threshold of community acceptability is important.

There may not always be a clear understanding of function/outcomes – but seeking the views of affected parties / communities of interest and network users will get us closer to this answer.

Scenario: Based on consultation with the local community, it was determined that one bridge predominately provided access to a rural school the community relied upon.

Primary outcome(s): Student participation in class

Options to create redundancy:

- Development of an additional route (bridge) to the school
- Provision of tablets to students to allow them to work from home
- Arrangement with the local hall to provide alternative accommodation should the bridge fail

Robustness

The ability to withstand disruption and continue to provide to an acceptable level of service

Characteristics:

Well conceived, constructed and managed **systems**

Includes the implicit concept of **robustness of a system**, as well as the physical characteristics of an asset under normal circumstances

Anticipates failure

Acceptable level of service allows for resilience measures to include the option of returning partial function of an asset/system within a certain time period based on tolerance of communities of interest

Scenario: Inland ports are becoming an important to step in the aggregation of freight for export, and there is particular reliance on the Timaru / Lyttleton link for the Port of Lyttleton.

Primary outcome(s): Provision of cost effective bulk transport from freight services via rail from Timaru to Port of Lyttleton

Options to create a robust system:

- Structural: additional drainage and bunding along the line to withstand more intense rainfall events
- Organisational: development and implementation (including audit) of a maintenance regime of a frequency which ensures the line can function in marginal temperatures

Recovery

The ability to restore an acceptable level of service after disruption

This definition includes important elements of:

Acceptability: Decision makers need to be fully aware of the acceptability of an loss of service for the asset in question.

Service: Decision makers should be aware of the service (outcomes) they are trying to provide for – not just focusing on the provision of new assets.

Ability: Restoration of service must be within the bounds of control of decision makers.

There may not always be a clear understanding of acceptable levels of service provision for a particular asset/part of the transport system – but consultation with local communities and network users will get us closer to this answer.

Scenario: A landslide occurs on SH2 near Kaikoura.

Primary outcome(s): Restore one lane to full operation within 1 day – as this will have marginal costs for freight, business and the community. It has been determined, that more than one day creates unacceptably high costs and risks for freight delivery and the affected community.

Options to improve recovery:

- Prior consultation with a community about the acceptable levels of outage on the asset
- Prior discussions with contracting companies – who have geographically diverse access to any disruption – to ensure that service can be restored regardless of where a landslide might take place
- Prior consideration of feasible traffic diversions (if relevant)

Governance and Leadership

*The ability to develop an organisational mind-set / culture of enthusiasm for challenges, agility, flexibility, adaptive capacity, innovation and taking opportunity**

Characteristics:

Leadership actively creates and supports the culture

Forward looking: The ability to identify, prioritise and address problems (also termed resourcefulness or situational awareness)

Responsive: capacity building to aid recovery and restoration (also termed rapidity)

Scope includes NZTA, organisations in NZTA's supply chain and communities of interest

Scenario: The Haast / Jackson Bay Road has overtopped more frequently in the last 5-years than the previous 20-years. The road is the only link between Haast and the small communities to the south.

Primary outcome(s): Provision of route to transport goods and fuel south of Haast

Options to support resilience from a governance perspective:

- Structural: encourage innovation within the engineering community to develop a surface that is less affected by brackish water
- NZTA: work collaboratively with subject matter experts to better understand the perceived increased frequency of events in the context of a changing climate to inform a response
- Community: formalise current approaches to fuel and goods storage so the community is not disrupted by overtopping events.

Definition of Terms

This glossary defines the specific meaning of certain words and phrases used in the public domain with regards to risk & resilience. In order to create a common understanding of risk & resilience, these terms should be used purposefully to mean the definitions provided. Where a different meaning is intended, a different word should be selected in order to begin to harmonise the lexicon of risk & resilience.

Where there is a New Zealand government defined definition, we have provided this *verbatim*, otherwise sources of the definitions have been included for reference.

Assets (at risk): Includes populations, systems, communities, the built domain, the natural domain, economic activities and services, trust and reputation; and other things we value which are under threat from hazards in a given area. This can also be described as elements (at risk)¹.

Communities of Interest / Affected Communities: Communities who are impacted by, or depend on, the transport system.

Consequence: An outcome of an event (that may result from a hazard) affecting objectives². It may be expressed quantitatively (e.g. monetary value), by category (e.g. high, medium, low) or descriptively. An impact on the natural, economic, built or social environment as the result of a hazard event. Consequences are influenced by the exposure and vulnerability of elements at risk (e.g. human like and property) to the hazard, and by the hazard characteristics.

Cultural: To develop through model testing

Disruption: To develop through model testing

Economic: To develop through model testing

Definition of Terms

Environmental: To develop through model testing

Exposure: People, property, systems, or other assets present in hazard zones or exposed to hazards that are thereby subject to potential losses.

Frequency: A measure of likelihood expressed as the number or rate of occurrences, usually for a given time period³.

Hazard / Threat / Challenge: A potential damaging physical event, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental damage^{1(modified)}.

All challenges are covered by this term, e.g. malicious, technological, natural etc. Hazards can be single, sequential or combined in their origin and effects. Each challenge is characterised by its timing, location, intensity and probability⁴.

Likelihood: The chance of something happening². This can be expressed as probability either quantitatively as a ratio (e.g. 1 in 10), percentage (e.g. 10%) or value between 0 and 1 (e.g. 0.1) or qualitatively using defined and agreed terms such as unlikely, almost certain, possible etc^{5(modified)}.

Mitigation: The lessening or limitation of the adverse impacts of challenges¹.

Residual Risk: The risk that remains after risk treatment has been applied to reduce the potential consequences⁴.

Resilience: The ability of systems (including infrastructure, government, business and communities) to proactively resist, absorb, recover from or adapt to disruption within a timeframe which is tolerable from a social, economic, cultural and environmental perspective.

Definition of Terms

Resilience Controls: To develop

Risk: The effects of uncertainty on objectives².

- an effect is a deviation from the expected (positive and/or negative)
- risk is often characterised by reference to potential events and consequences, or a combination of these
- risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

Modern thinking on risk, as set out in ISO 31000, provides a particularly helpful approach to dealing with actual and potential threats and opportunities. One of the key paradigm shifts in ISO 31000 is a change in how risk is conceptualised. The definition of "risk" is no longer "chance or probability of loss", but "the effect of uncertainty on objectives" ... thus causing the word "risk" to refer to positive possibilities as well as negative ones. Risk therefore needs to be considered in the context of objectives (i.e. the function or provision of service within a system).

Risk Treatment: Measures taken to reduce the consequences of a hazard (e.g. through risk avoidance, reduction/mitigation, transfer or retention/acceptance). Cannot typically remove all risk⁴.

Shocks: Sudden, sharp events that threaten a system, such as earthquakes, floods, disease outbreaks and terrorist attacks⁶.

Social: To develop through model testing

Definition of Terms

Stresses: Longer term challenges that weaken the fabric of a system^{6(modified)}.

System: The 'system' includes both the transport network and the communities that depend on the system.

Tolerance: community of interest acceptance to an asset being unavailable, or available at reduced capacity, for a defined period of time.

Uncertainty: The state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequences or likelihood².

Vulnerability: The characteristics and circumstances of elements of risk (e.g. human life, asset or property) that make them susceptible to, or protected from, the damaging effects of a hazard⁵.

1. UNISDR

2. ISO 31000

3. AGS (2000)

4. Provided by MfE, March 2016

5. LGNZ (2014) Managing natural hazard risk in New Zealand – towards more resilient communities. October 2014

6. Rockefeller Foundation

Appendix B

Literature cited



Literature Review

Around 100 reports identified

- 16 pieces of key literature considered in detail
- 75 pieces of other literature cited

Wide range of definitions of resilience – although there are number of common threads

- Researchers working on the *Resilience Benchmarking and Monitoring Review* accumulated 120 distinct definitions of resilience from peer-reviewed academic literature and policy and industry literature

A constantly evolving wealth of well-researched, well-reasoned, contributions to the resilience body of literature already exists - New Zealand also has a lot of good discrete contributions - but nothing that pulls all of this together

Limited economic assessment of wider costs or broader (indirect) benefits

Limited consideration of localised ‘tolerance’ towards disruption

- Bruneau et al. (2003) refer to the ‘quality of infrastructure for a community sitting between 100% and 0%’ - i.e. contemplates a scalable assessment of community dependence on assets.
- State Highway Network Resilience National Programme explicitly refers to ‘understanding the vulnerability of communities to disruption’

Strong focus on shocks rather than stresses – natural hazards often drivers for research