MBIE Extreme Weather Science Response Funding

Supporting Critical Infrastructure Recovery

Building resilience through recovery: Investment decision making

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The 2023 North Island extreme weather events caused significant damage to critical infrastructure, leaving communities without service for days to weeks. This event highlighted the fragility of New Zealand's critical infrastructure systems and presents an opportunity to build in resilience during the recovery works - including what, where and how to build infrastructure (or not).

The rebuilding process is an opportunity to operationalise the goals within the National Disaster Resilience Strategy (NDRS). This strategy defines resilience as:

> *"the ability to anticipate and resist the effects of a disruptive event, minimise adverse impacts, respond effectively, maintain or recover functionality, and adapt in a way that allows for learning and thriving."*

Critical infrastructure resilience frameworks from around the world have been reviewed to identify different approaches to integrating resilience into infrastructure rebuild and investment decision-making. This brief provides a checklist through each stage of the assessment and decision-making process against which infrastructure providers/planners/decision makers can ensure that existing they are effectively integrating resilience thinking into their decision making processes and recovery plans.

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Stage 1: Define the problem

The problem-framing stage is the crucial first step in resilience planning. It involves identifying objectives and clearly defining the challenges that need to be addressed to enhance the resilience of critical infrastructure systems to future hazard events. By defining the problem, decision-makers can lay the foundations for the development of effective strategies and actions to mitigate risks, enhance preparedness, and build resilience.

- Identify the specific needs of diverse communities to ensure that infrastructure resilience planning caters to the entire community. This should be done in consultation with the public to get a diverse set of views and needs across gender, age, ability, and ethnicity (including visitors) and in partnership with Iwi and key community stakeholders.
- Identify the levels of service required to meet community needs (e.g., water supply, essential goods, transportation connectivity between places) following a disruption. Needs could be different across the community (e.g., essential community services, residential vs industrial users, low v high density areas). Needs will also change over time, as tolerance to reduced levels of service wane and emergency supplies are depleted.
- Identify the dependencies on other infrastructure networks – those that depend on you and those you depend on. This can be done through workshops or modelling looking for connections that are: **physical** – there is a direct physical connection, and one asset is reliant on another asset to function; **informational** – information from one asset is required for another asset to function; **geographic** – assets are co-located and damage to one can affect the function of the other; and **logical** – assets are connected through some human factor such as legislation, financial markets, supply chains, etc. Existing forums such as regional lifeline groups are useful vehicles to determine and understand dependencies.
- Identify and engage with all relevant stakeholders including first responders, other infrastructure providers, and regional and national emergency management organisations. These discussions will identify estimates of the duration of disruptions, priority for reinstatement (based on dependencies) and identify the resources and capacity for support during response and recovery.

Stage 2: Hazard and damage assessment

A **risk-based approach** uses hazard and damage assessments to provide information on predicted damages to infrastructure following a disruptive event. This information can then be used in combination with a criticality assessment (Stage 3) to prioritise interventions and again in the option selection stage (Stage 5) to provide quantitative measures of resilience.

A risk-based approach involves the overlay of potential hazards (earthquake, flood, tsunami etc) onto infrastructure assets (i.e., the individual components within each network) to identify exposure. Vulnerability or fragility of each component translates this exposure into asset damage. These damages are

Figure 1: Risk is the combination of hazard, exposure, and vulnerability (United Nations n.d.)

evaluated using damage thresholds or fragility curves. Damage thresholds are often binary and show the level of hazard above which an asset can no longer function. Fragility curves model the relationship between hazard severity (e.g., flood height) and degree of asset damage.

- Consider both extreme, worst-case scenarios and more frequent, lower-impact events to comprehensively assess the resilience of infrastructure systems. Use historical data, trends, experts, and modelled hazard projections to evaluate the spatial distribution of hazards and where infrastructure assets are exposed. Where possible, account for projected changes to hazards (e.g., climate change induced sea level rise and flooding) using hazard scenarios.
- Scenarios should be used to investigate network effects, exploring different ways failures could cascade through the network.
- Use fragility curves or stakeholder-based damage thresholds to determine the extent and degree of damage.
- Account for planned infrastructure upgrades, future population changes, and technological changes.

Risk-based approaches are data intensive, requiring hazard maps showing the spatial extent of specific hazards and how they may change in the future. These changes should be well defined through use of probability distributions or forecasts. The quality of a risk-based approach is often heavily dependent on the amount and quality of both asset and hazard data available, as well as the degree of uncertainty. In cases where hard data is not present, or there is substantial uncertainty in the hazards, an all-hazards approach could be used instead.

All-hazards approaches apply general robustness concepts to decision-making, circumventing the need for precise data on hazard extents and frequencies, and aim to be resilient to a wide range of events rather than optimised for well-described events. This is done by applying concepts like redundancy and resistance during the plan/option development stage (Stage 4). An all-hazards approach is more aligned to an 'agree-on-decisions' approach, where you design plans and then evaluate them across a range of possible hazard impacts rather than an 'agree-on-assumptions' approach where you predict the disruption/hazard and design for it. This means that during the option selection stage (Stage 5) a range of possible hazard scenarios are required to evaluate the effectiveness of proposed interventions. The lack of damage data also means that the prioritisation stage (Stage 3) is largely driven by asset or network component criticality.

Stage 3: Criticality assessment and prioritisation

The criticality assessment stage plays a vital role in resilience planning by identifying and evaluating the impact of loss of function on the community/users. This moves beyond the physical disruption to the likely socio-economic impacts on the community. By assessing the criticality of each aspect of an infrastructure network/system, decision-makers can allocate resources effectively and prioritise investments in the components of the network that provide the greatest resilience benefits.

If you are using a risk-based approach, prioritisation is generally based on a combination of likely damage to the network (based on the hazard and impact assessment) and criticality. For an all-hazards approach, criticality measures alone can be used to prioritise investment.

There are many dimensions of criticality that can be considered individually or in combination:

- The importance of infrastructure assets to the overall functioning (business-as-usual) and well-being of the community, including consideration of cultural significance.

- The importance of infrastructure assets and networks to future recovery processes, which may differ from their typical day-to-day importance.
- The number of people served and the significance of the user's needs (including critical customers such as hospitals and civil defence centres).
- The upstream and downstream dependencies between different infrastructure assets and sectors. Failure of infrastructure systems your asset/network requires to function (upstream dependencies) can nullify any interventions you implement. Downstream dependencies can exacerbate impacts of failure, through cascading impacts on other critical infrastructure systems.
- The vulnerability of the community and its capacity to withstand loss of service and/or recover from disruption. Areas that don't have resources or are particularly vulnerable may be more important to service.

Stage 4: Plan or option development

The plan development stage involves the formulation and design of robust and coordinated resilience plans or options based on the desired performance outcomes, the hazard and risk assessment (for a risk-based approach), and the criticality assessment. Approaches to increase resilience range from emergency preparedness measures to asset/network design.

Emergency preparedness:

- Establish resource stockpiles and backup components to enable prompt response and recovery operations during/after disruptive events.
- Ensure that local areas have the necessary resources and capabilities to support their recovery efforts in the event of a disruptive event. This can be supported through supplier agreements and working with emergency managers to understand prioritisation.
- Explore alternative approaches and strategies to maintain basic community needs even if specific assets or services are compromised or unavailable.
- Provide backup or understand what alternative options critical customers have in place to ensure the continuity of essential functions during infrastructure outages.
- Implement measures to reduce demand on infrastructure assets during periods of lower capacity or disruption to ensure their continued functionality.
- Remove potential hazards to decrease the possibility/severity of damage (e.g., slope stability improvements, pruning of trees near powerlines).

Asset/network design:

- Relocate assets to safer areas to minimize potential damage and disruption.
- Diversify asset locations in order to diversify the hazards that networks are exposed to. This reduces the chance that all assets will be affected by the same event.
- Incorporate redundancy in infrastructure systems e.g., N+1 configuration, ladder networks, etc. to minimize disruptions to end-user service delivery.
- Strengthen assets to withstand larger hazard intensities without loss of service.
- Use safe-to-fail design to allow for controlled failure on the assumption that the possibility of failure can never fully be eliminated.
- Apply adaptive planning principles to infrastructure planning when hazards are changing with time. This involves monitoring conditions to ensure that assets can resist changing hazards and designing assets to allow for future modification should conditions change.

Often this will involve more upfront costs. For example, over-engineering foundations so that in future modifications to the structure can occur without the need to redesign/replace previous foundations.

Stage 5: Plan or option selection

The plan selection stage focuses on evaluating and selecting the most appropriate resilience plans from the options developed during the plan development stage. It involves a careful analysis of the feasibility, effectiveness, and cost considerations of each plan. When using a risk-based approach, intervention options can be tested within the hazard and damage assessment model to evaluate the direct benefits of the intervention (comparing impacts with and without the intervention). When applying an all-hazards approach use a range of possible hazard scenarios to investigate how different futures change the measure of resilience of a given plan.

- Plans and options should be compared to a “do nothing” scenario. There should be a measurable increase in resilience/performance. Measurements to consider could include:
  - Time to recover to pre-event levels.
  - Time to recover basic community needs.
  - Damages avoided (commonly expressed in dollars).
  - Casualties avoided.
  - Socio-economic benefits (avoided losses).
  - Number of failure mechanisms.
  - Number of dependencies within networks.
  - The magnitude of disruptive event to be able to be withstood.
  - The number of systems that have backups and duplicates.
  - Adaptability to changing hazard and community needs.

  Decision-makers should also assess the alignment of the plans and options with the identified goals, objectives, and priorities of resilience planning.

- Collaborate and seek consensus among various stakeholders, including government entities, industry representatives, iwi, and community members, to ensure a comprehensive and inclusive resilience planning process.
- Try to align plans across different infrastructure entities leveraging synergies and avoiding trade-offs where possible.
- Look for synergies and avoid trade-offs, if possible, with business-as-usual operations. There may be tension between resilience plans and business strategies like just-in-time delivery.

Stage 6: Implement plan or option

The plan implementation stage involves translating the developed plans into actionable initiatives, allocating resources, and coordinating the implementation. Implementation may require a phased approach, prioritising basic community needs and areas with higher vulnerability.

- Engage with stakeholders and the public around the recovery process, their roles, and how they can contribute to infrastructure management.
- Establish clear communication and command structures to facilitate effective coordination and decision-making during response and recovery efforts.

- Implement information systems or standardise data sets to facilitate information sharing and coordination among infrastructure operators and stakeholders during recovery operations.
- Communicate the level of service expected after a disruption event indicating possible recovery times. This will help communities and critical customers with their own resilience/emergency preparedness planning.
- Take advantage of disruptive events as opportunities for learning, evaluation, and improvement, to enhance resilience and future planning.

For more on implementing critical infrastructure recovery programmes, refer to the companion brief Mace and Brown (2023) Critical Infrastructure recovery: Key lessons. (https://www.resorgs.org.nz/wp-content/uploads/2023/07/NIEWE_critical_infrastructure_-recovery_key-lessons.pdf).

Image reference

United Nations. n.d. "Disaster Risk Management." UN-SPIDER Knowledge Portal. Accessed July 6, 2023. https://www.un-spider.org/risks-and-disasters/disaster-risk-management.