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RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Short-Term Project: Working Paper, Deliverable 1

Resilience Benchmarking & Monitoring Review

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Deliverable 1: Overview

New Zealand is at an exciting point in its trajectory towards becoming a leader and exemplar of disaster resilience. The Government, through the Ministry of Business, Innovation, and Employment (MBIE), is funding the National Science Challenges (NSC) through its partner GNS Science. The NSC funding format encourages cross-disciplinary and cross-institutional collaboration and strategic planning to enact transformative change through best-practice research.

The Resilience to Nature's Challenges (RNC) – Kia manawaroa Ngā Ākina o Te Ao Tūroa - priority research area under the NSC umbrella aims to achieve, "transformative resilience, discovering and implementing new research-based solutions for our society, culture, infrastructure and governance to address factors that will enable New Zealand to thrive in the face of nature's challenges," (Jolly 2014).

An important part of the RNC research programme will be mapping and monitoring the trajectories of the various systems that contribute to New Zealand's resilience. Prior to the launch of the RNC in July 2015, RNC researchers conducted a short-term project to provide a foundation for understanding how we can benchmark the resilience of New Zealand's systems and monitor resilience progress.

This short-term project, The Resilience Benchmarking and Monitoring Review, is intended to provide an inclusive, up-to-date resource of theoretical and practical resilience frameworks and reviews of current resilience literature and relevant datasets. The deliverables produced as part of this short-term project will be used across the RNC-NSC to aid the usefulness, consistency and robustness of resilience benchmarking and monitoring. The deliverables will also aid the development of the work-plan for RNC-NSC Toolbox 7: Resilience Trajectories.

This working paper provides a summary of the work undertaken as part of The Resilience Benchmarking and Monitoring Review. Section 1 addresses the definition of resilience as it pertains to disasters. Although a large number of articles grapple with the definition of resilience, the authors felt it was necessary to attempt to facilitate a common understanding across the RNC by providing a robust cross-disciplinary interpretation of the concept. Section 2 addresses conceptual questions raised by stakeholders during the short-term project expert consultation phase or questions that emerged from the literature review which will likely need to be addressed by the Resilience Trajectories Toolbox and other priority research areas in the future. Section 3 discusses operationalizing resilience to make practical changes for New Zealand communities. Section 4 outlines the multi-capital framework that underpins the holistic approach to resilience assessment in the RNC-NSC. Section 5 provides a brief review and critique of frameworks and assessment and monitoring tools that may inform the resilience research agenda over the next several years. Finally, Section 6 reflects on the conclusions of The Resilience Benchmarks and Monitoring Review and maps research plans and priorities emerging from this review.

A short note on methods: To develop the deliverables associated with this short-term project the research team conducted a thorough literature review. The literature review was conducted using systematic sampling of sub-sets of the resilience literature: human/psycho-social resilience, organizational/institutional resilience, infrastructure resilience, social-ecological systems, community resilience, and disaster resilience theory. The coverage is biased toward highly cited and influential literature in this field and research perspectives and empirical research developed in New Zealand. The deliverables are also informed by 18 semi-structured key informant interviews with resilience, DRR, and data experts in New Zealand and Australia, and 11 unstructured consultative interviews with field experts and stakeholders in New Zealand, Europe, and the U.S. This combined 40+ hours of discussion between April 2015 and June 2015, provided substantial guidance and information for the deliverables associated with this project. In keeping with the co-creation and design thinking approaches endorsed by RNC-NSC, parts of these deliverables were work-shopped with key stakeholders, presented to programme leaders within the RNC-NSC, and reviewed by an expert panel creating an iterative feedback and refinement process. This process will continue to evolve beyond this three-month project.

1 Defining Resilience

Resilience is a term with applications across a number of academic fields. It is also a term that has been drafted into common usage in media and policy circles. Its numerous interpretations, reinterpretations, and misinterpretations have led to growing concerns from disaster risk reduction and related climate change adaptation (DRR-CCA) researchers and practitioners that resilience is a concept with so little clarity and so few boundaries that it has or is becoming an impotent buzzword similar to that encountered by the term sustainability. Hence there is a serious need to define resilience as it is applicable to the RNC-NSC.

Specific concerns raised in discussions during the Resilience Benchmarking and Monitoring review include sentiments such as:

- There are so many definitions of resilience it can mean anything to anyone. How can we possibly assess the “resilience” of complex social systems or places?
- We already have a number of useful concepts in DRR-CCA, such as risk, recovery, preparedness, mitigation, sustainability, vulnerability, and adaptive capacity. Resilience does not add anything new to the conversation, and may be an unhelpful distraction from progress in these arenas.
- Even if resilience is conceptually a valid and distinct term, there are not clear pathways to operationalize resilience through policy and practical interventions. We are better off focusing on areas that are more tangible for people working on the ground, such as recovery planning, sustainable development, and risk reduction.

These concerns should be addressed before advancing the development of a national resilience strategy or research agenda. Effective measures and interventions critically depend upon the underlying conceptualization and the epistemological background that guide those actions (Birkmann et al. 2012a). Thus, the obvious place to begin is with the definition of resilience.

1.1 Definition Analysis

Researchers working on the Resilience Benchmarking and Monitoring Review short-term project accumulated 120 distinct definitions of resilience from peer-reviewed academic literature and policy and industry grey literature. The earliest definition in this analysis is Holling’s (1973) influential depiction of ecosystem resilience. However, the majority of definitions (88%) come from sources published between 2000 and 2015, reflecting some bias in the accumulation of resources but also reflecting the proliferation of the term across academia and beyond in the last decade and a half.[1] The definitions come from a variety of perspectives and fields and the definitions were developed in reference to the resilience of community, psychological, ecological (including social- and human-ecological), institutional and organisational, infrastructure, and other engineered systems.

A simple word frequency analysis of the definitions shows a number of common concepts within the definitions. Of the 25 most frequently used words across the 120 definitions of resilience (**Table 1**), seven referred to an event or event descriptor: event, disaster, stress, shock, disturbance, impact, and hazard.

Table 1: Top 25 words used in definitions of resilience

Word	Count	Similar Words (included in count)
ability	61	Ability
adapt	47	adapt, adaptability, adaptation, adapted, adapting, adaptive, adaptively
capacity	34	capacities, capacity
recover	31	recover, recovers
event	25	event, events
disaster	22	disaster, disasters
function	21	function, functional, functionality, functioning, functions
absorb	17	absorb, absorbed
stress	16	stress, stresses
shocks	16	shock, shocked, shocks
adversity	14	adverse, adversity
process	14	process, processes
disturbance	13	disturbance, disturbances
maintain	12	maintain, maintaining
cope	12	cope, coping
impacts	12	impact, impacts
return	11	return, returns
back	10	Back
respond	10	respond, responding
hazard	10	hazard, hazardous, hazards
resist	9	resist, resisting
bounce	9	Bounce
level	9	level, levels
state	9	State
face	8	Face

[1] The literature we analysed was almost exclusively published in "Western" countries: the United Kingdom, Europe (especially Northern European countries), the United States, Australia, and New Zealand, and the majority of case studies and empirical research were also conducted in Western countries.

The analysis offers insights into the common interpretations of the behaviour of the resilient system, including words like adapt, recover, function, absorb, maintain, cope, return, respond, and resist. These 'behaviour words' roughly fall into four temporal categories: 1) upon impact (absorb, cope, resist, maintain), 2) response phase (respond), 3) recovery phase (recover, return), 4) preparing for the altered present and the future (adapt). Function is often used in reference to the impact phase, as in "maintain function, " and the recovery phase (e.g. recover or return functions).

Another set of behaviours often associated with resilient systems but not captured in the word frequency analysis includes the ability to reduce or mitigate (as well as absorb and resist) the adverse impacts of a disruptive event. Additionally, the resilience literature very regularly includes learning, growth, exploitation of opportunities, and positive adjustment and the ability to mitigate future disruptions. These would fit into the category along with adaptation as behaviours that enable a system to prepare to function well in an altered present and into the future. Due to the complexity of both of these concepts they are described using a wide array of terminology.

The word frequency analysis shows that resilience is often referred to as an ability or capacity of a system, and slightly less commonly a process. When resilience is referred to as a "process" the authors are generally trying to convey a sense of dynamism. *Becoming* resilient or *maintaining* resilience is a process. Resilience itself is no more a process than intelligence and physical fitness are processes; these are states or characteristics that can be achieve or maintain through a process. References to resilience as a process further highlight the need to have a robust, unifying definition. Most authors believe that "resilience" is best described as a trait-like ability (Shin et al. 2012) or characteristic capacity (Cox & Perry 2011, Luthans et al. 2006, Mayena 2006, Mueller 2013).

1.2 Developing a meta-definition

Here we propose a meta-definition of resilience that draws together the commonalities from across the disaster resilience literature. Resilience is:

> **The ability to absorb the effects of a disruptive event, minimize adverse impacts, respond effectively post-event, maintain or recover functionality, and adapt in a way that allows for learning and thriving, while mitigating the adverse impacts of future events.**

This meta-definition captures resilience as systemic, and reflects the dynamic processes that contribute to the development and maintenance of this ability.

Definitions that resemble this meta-definition include the National Research Council's (2012) description of resilience as,

> "The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events,"

Cutter et al.'s (2008) description of social system resilience as,

> "The ability…to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to reorganize, change, and learn in response to a threat," and

Jordan and Javernik-Will's (2012) definition of community resilience as,

> "The ability to withstand disaster impacts as well as to cope with those impacts and recover quickly. It can be thought of as a function of inherent resilience, the ability to withstand impacts without extensive losses, and adaptive resilience, the ability to adapt and access resources to cope with a disaster and recover."

The United Nations International Strategy for Disaster Reduction (UNISDR) (2009) also comes close, but does not include explicit reference to adaptability,

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

The UNISDR's (2005) definition, however, does include a reference to a system's capacity to adapt.

Finally, the New Zealand Treasury's National Infrastructure Plan describes resilience from a policy context in a way that is also very close to the meta-definition proposed here:

> "The concept of resilience is wider than natural disasters and covers the capacity of public, private and civic sectors to withstand disruption, absorb disturbance, act effectively in a crisis, adapt to changing conditions, including climate change, and grow over time," (Hughes & Healy 2014, p. 7).

The meta-definition and the accompanying similar definitions discussed here refer specifically to resilience as an outcome. The definitions also refer to a set of processes (e.g. absorbing, recovering, adapting) that jointly contribute to the achievement of that outcome.

2 Embracing plurality

Despite identifying numerous common themes of resilience as it is characterised across a range of perspectives, we cannot imply that there is consensus about the way resilience is interpreted. It may be that some aspects of resilience are more prominent or important for different systems. So although we can start from a common definition as an orienting point, it is practical and necessary to accept a plurality of resilience frameworks and metrics that are tailored to the system of interest. For example, characterizations of resilience developed for engineered systems emphasise elements that are particularly relevant for the built environment such as robustness, redundancy, rapidity (of return to function), and resourcefulness (Bruneau et al. 2003). Conversely, characterisations of community or social resilience are more likely to refer to development, learning, and human interactions and relationships (Mueller 2013, Paton 2006, Sonn & Fisher 1998).

Particular operational definitions that emphasise or leave out certain aspects of the meta-definition proposed may be appropriate when approaching resilience assessment in a given field or at different scales of analysis. It is important to recognise that although we propose a unified meta-definition of resilience, there will be important practical differences when assessing the resilience of regions, communities, and individuals and the resilience of ecological, social, organisational and built environments.

For example, Allenby and Fink (2005) define resilience as, "the capability of a system to maintain its functions and structure in the face of internal and external change and to degrade gracefully when it must," (Allenby and Fink 2005, p. 1034). The concept of degrading gracefully is especially relevant in engineered systems that need to be designed to fail safely (Hughes & Healy 2014).

While it is important to recognise and accommodate these differences, there are several incongruities or conflicts around the conceptualisation of resilience that obstruct holistic approaches to resilience. These can be addressed to enhance common interpretations and move the research agenda toward operationalizing resilience. These conflicts stem from:

- References to ideas of return or bouncing back to a previous or equilibrium state,
- A lack of clarity about the relationship between adaptation, adaptive capacity, and resilience; and vulnerability, recovery, and resilience.

Each of these is addressed below.

2.1 Is bouncing back OK?

There remains a conceptual divide between characterisations of resilience as a system's ability to 'bounce back' or return to a state defined prior to disruption and those that see bouncing back as either impossible or regressive. This debate has evolved significantly in the past decade, after 2010 very few definitions incorporate the idea of bouncing back.

The 'bounce back' terminology stems from materials science where resilience is understood as "the ability [of a material] to bounce or spring back into shape, position, etc., after being pressed or stretched," (O'Rourke 2007). Bouncing back to a previous state, however, may not be possible in complex social and ecological systems.

When defining a national resilience research agenda for New Zealand we may want to focus less on 'bouncing' and instead emphasize exploring divergent paths to a more resilient future.

This represents an important difference between engineering and social-ecological approaches to resilience. As resilience has been translated from material (engineering) science to ecology and social science, theorists have developed more integrated approaches to resilience, that focus less on the attainment of equilibrium and giving more emphasis to interaction between systems and to learning, innovation, and opportunity seeking (see **Table 2**).

Table 2: A sequence of resilience concepts

Resilience perspective	Characteristics	Focus on	Resilient states
Engineering resilience	Return time, efficiency	Recovery, constancy	Vicinity of a stable equilibrium
Ecological/ecosystem resilience	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscapes
Social-ecological resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity, transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interactions

Source: adapted from Folke (2006, p. 259)

Researchers disagree about whether equilibrium, or a stable state to which a system can return, exists at all for living systems. Some suggest that systems experience continuous state changes through adaptation (Alexander, 2013; Burton, 2012; Klein et al., 2004). Complex systems are continuously exposed to perturbations, and therefore the system often needs to adapt in order to continue functioning in the changed environment (Gallopín 2006).

Those that argue that bouncing back is regressive feel that the return of a system to a pre-disruption state will often mean re-establishing vulnerabilities (Manyena et al. 2011, Stewart, Kolluru, and Smith 2009) or that 'bouncing back' favours short-term responses over long-term adaptation (Birkmann et al. 2012a). Rose (2007), for example, argues that emphasis on return to a pre-existing state may leave businesses and economies more vulnerable to future disasters if long-term investment in improvements are traded-off for rapid reinstatement.

For complex systems, references to return, recovery, or bouncing back should be associated with the retention or recapture of positive, functional aspects of the system and integrated with the expectation of learning, finding new opportunities, adaptation, and development. These attributes allow systems to continue to thrive in dynamic environments. Psychological resilience, for example, has long been characterised as the ability to bounce back to a previous level of functioning following adversity, which often requires adaptive responses and does not preclude post-traumatic growth (Karanci and Ikizer 2012). This is also true of community resilience. For example, the Wellington Region Emergency Management Office's (WREMO) (Neely et al. 2013) explanation of community resilience refers to the capability to "bounce back rapidly," but specifies that this be achieved, "through survival, adaptability, evolution, and growth in the face of turbulent change."

Authors occasionally advocate for the phrase 'bouncing forward' in place of bouncing back (Cox & Perry 2011, Manyena et al. 2011). However, Karanci and Ikizer (2012) offer a compelling warning about the implications of this phrase,

> "It could be suggested that this phrase [bounce forward] bears an implicit message that resilient communities are such because they strive to regain, and even accelerate, some sort of pre-event trajectory," (p.14).

This again highlights the concern about the trade-off between recovery speed and reflective adaptation. Setting a resilience building agenda based on bouncing in either direction (back or forward) connotes moving along a trajectory that was defined prior to the disruptive event and may be out-dated or uninformed by the lessons of the disruptive event. As Karanci and Ikizer (2012, p.14) ask, "Would not arguments focused on the adaptive nature of resilient 'systems' be better illustrated by the inclusion of more divergent path alternatives?" 2.2. Is resilience just another term for adaptive capacity?

There is lack of consensus in the literature about the relationships between adaptation, adaptive capacity, and resilience (Bahadur, Ibrahim, and Tanner 2010). The 'meta-definition' proposed earlier includes the capacity to adapt as a fundamental, but not the singular, element of resilience. Some authors, however, consider adaptive capacity the defining characteristic of a resilient system (Becker, Paton, & McBride 2013, Paton 2006, Thornley et al. 2014). Klein et al. (2003) see resilience as a factor of the larger umbrella concept of adaptive capacity, and argued that enhacing and maintaining adaptive capacity should be the overall goal of resilience. Similarly, Norris et al. (2008) define community resilience as, "A process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance," (p. 130).

Scholars approaching resilience from the social-ecological perspective argue that adaptive capacity reflects learning, the flexibility to experiment and adopt novel solutions. This work notes that adaptive capacity is just one (important) dimension of system resilience (Glavovic 2015, Walker et al. 2001).

In a policy and practice context, it is important to consider resilience as a goal or development *outcome* and adaptation as a *mechanism* or *process* to move the system closer to that outcome. Recognising resilience as a set of desirable traits or abilities clarifies what the policies should aim to achieve. Processes that facilitate adaptation can then be built into strategies to achieve and maintain those defined resilience traits or abilities. In addition to developing adapative capacity it is also beneficial to find ways to maintain factors that are already contributing to resilience (e.g. enhance robustness, retain some system redundancies).

An exclusive focus on adaptation occurs at the expense of understanding factors that enhance the capacity to absorb or cope with adverse events. In assessing infrastructure and economic resilience, for example, Vugrin et al. (2010) recommend evaluating the system's absorptive and restorative capacity in addition to its adaptive capacity. Similarly, the Disaster Resilience of Place (DROP) Model links multiple capacities including absorbing disruption impacts, coping with disruptive events, and adapting in a way that facilitiates the ability of the social-system to reorganize (Cutter et al. 2008). Recognising the relevance of multiple system capacities we can develop policies and practices that both build and sustain resilience.

2.3 Where does resilience sit in relation to risk, recovery, and sustainability?

Alexander (2013) warns against seeing resilience as a panacea paradigm for the future, arguing that some of the suspicion about the term resilience in disaster risk reduction discourse stems from the concept being pushed to "represent more than it can deliver," (p.1271). It is important to set boundaries around what resilience is and is not. This is especially important when considering approaches to resilience assessment and monitoring, as knowing what it is you want to achieve is an essential foundation for mapping a path forward.

There are a number of other concepts that are important in New Zealand's disaster research, practice, and policy landscape. Although resilience has become a popular frame from which to approach disaster-related challenges, it cannot replace other critical concepts including risk, recovery, and sustainability.

The New Zealand Treasury has explored the relationships between risk, resilience, and sustainability as shown in **Figure 1**, conceptualising the knowledge of risk and risk management practices as part of the creation of resilience. The figure then shows resilience (and resilience enhancement and management strategies) as part of the creation of sustainability.

Risk is, "the combination of the probability of an event and its negative consequences," (UNISDR 2009). A broader interpretation offered by the international risk management standard (ISO 31000:2009) defines risk as the "the effect of uncertainty on objectives – positive and/or negative," (p.1). Risk management is, therefore, the "systematic approach and practice of managing uncertainty [i.e. for 'known unknowns'] to minimize potential harm and loss," (UNISDR 2009).

Resilience includes preparing for and attempting to reduce known risks. Managing for resilience also includes developing capacities to deal with disruptions that have perhaps not yet been imagined or that are so rare, that doing targeted preparations would be a poor use of resources. Additionally, unlike risk management resilience management also strives to position systems to find opportunities, improve, and learn in the face of disruption.

Finally, sustainability provides a broader inter-system perspective. There are many definitions and interpretations of sustainability, but the most widely accepted definition is from the Bruntland Commission, which defines it as, "[meeting] the needs of current generations without compromising the ability of future generations to meet their own needs," (Bruntland Commission 1987, p.23).[2] In relation to risk, sustainability means that in addition to reducing existing risk, the management of systems avoids creating new risk (Saunders & Becker 2015).

Managing for risk, resilience, and sustainability can require thinking along different time scales. Authors such as Grubinger (2012) clearly link interpretations of resilience and sustainability to differential time scales (i.e. enhancing resilience requires relatively short-term planning to cope with sudden or acute shocks, while enhancing sustainability requires long-term planning to deal with more slowly emerging system changes). A way to frame this difference that does not require the specification of planning timeframes, is to consider the degree to which a system shifts in response to disruptions. Resilient systems are able to *adapt* to stimuli in their environments to retain or quickly regain optimal functionality, whereas sustainable systems may require more substantial *transformation* to retain some approximation of their functionality and to avoid compromising the functionality of systems to which it is linked (Grubinger 2012).

A strategy geared toward enhancing system resilience may not be adequate for adjusting to inter-generational, complex system interactions. These kinds of shifts require a system to transform aspects of its functional regime while still maintaining its overall integrity (Holling et al. 1995). For example, a coastal community may be able to develop strategies that enhance their ability to reduce the adverse effects of storm surge and flooding, and adapt in the aftermath of disruption. If the issue is exacerbated by coastal erosion or permanently altered by climate change, however, the community will need to transform (e.g. relocate or alter the structure of their economy) or risk becoming unsustainable.

The goal of resilience is foremost to reduce the negative impact of disruptive events, therefore reduce the need to recover. Resilience will assume a reduction in the need to recover but will not eliminate the need to recover entirely. For example, salutogenic approaches to resilience in social-psychology

[2] Though the Bruntland Commission definition is widely cited it is still highly contested, in much the same way that definitions of resilience are contested in different policy, research, and practice contexts.

emphasise factors that contribute to health and wellbeing regardless of exposure (Antonovsky 1987). Meaning that positive adjustments that enhance resilience and sustainability can be made without risk exposure and adversity, but not in every possible case. For instance, in building and infrastructure resilience damage is always likely in the event of a major disaster, but the level of resilience dictates recovery profiles. Developing capacities before a disruption can have benefits to the 'normal' functioning of system as well as contribute to greater disaster resilience capability to enable quicker recovery.

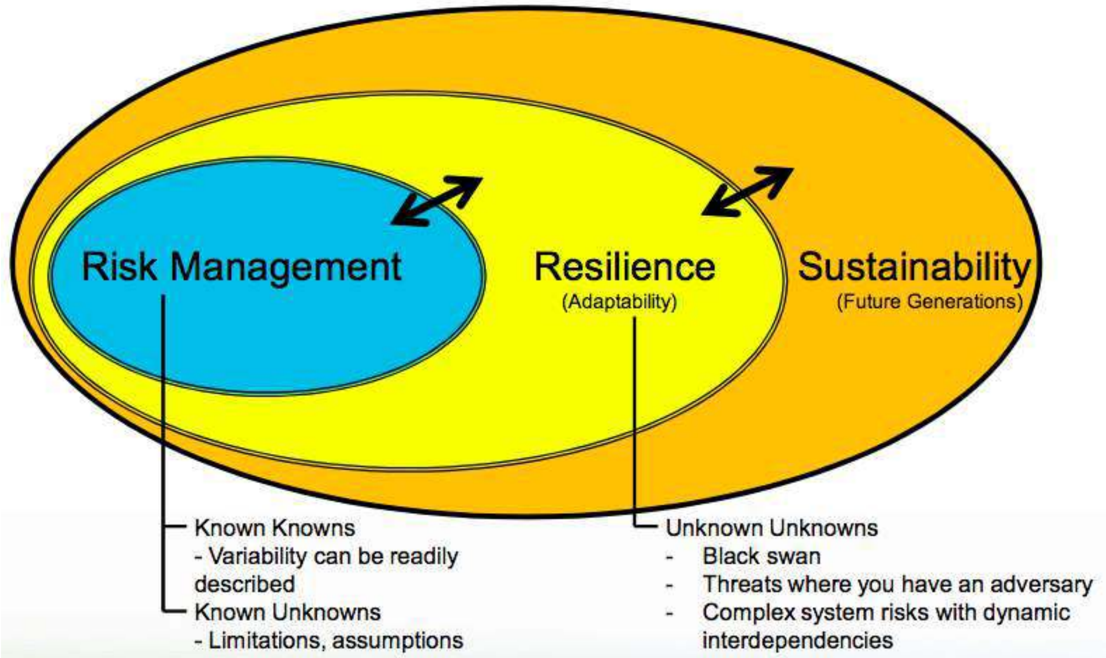


Figure 1: The Relationship Between Risk, Resilience, and Sustainability from the Treasury Living Standards Framework (Fairclough 2015)

Sustainability does however require resilience to disruptions. To support this argument, Saunders and Becker (2015, p.3) cite the UN Commission on Sustainable Development, which states, "Sustainable development…cannot be successful without enabling societies to be resilient to natural hazards."

Understanding the relationship between resilience and sustainability is important in the New Zealand policy environment. Several key pieces of legislation including the Resource Management Act (RMA), the Civil Defence Emergency Management Act (CDEMA), the Building Act, and the Local Government Act refer specifically to sustainability, but also have important implications for the development and monitoring of resilience (Saunders & Becker 2015). Land use zoning, pre-disaster recovery planning, and post-disaster response and recovery interventions need to consider both resilience and long-term sustainability (Saunders & Becker 2015).

2.4 Resilience and vulnerability

Vulnerability and resilience are interrelated. Often researchers will attempt to measure the two concepts with similar, if not the same, variables. Different interpretations across the DRR-CAA literature make it unclear whether social vulnerability and social resilience are opposite ends of the same continuum or perhaps two interrelated constructs that often overlap (Burton 2015). When measuring the vulnerability of a community do you need to know how resilient it is and vice versa?

This review does not pretend to have definitive solutions to these issues. We do, however, propose that vulnerability and resilience are distinct concepts that co-exist within social systems. As a result of this co-existence, the presence of vulnerability does *not* mean the lack of resilience, and the two concepts need to be assessed using different measures.

Vulnerability in a DRR context generally refers to the "characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard," (UNISDR 2007).

Brooks (2003) proposes a more nuanced view of vulnerability that accounts for the differences (and occasional contradictions) between biophysical vulnerability and social vulnerability. *Biophysical vulnerability* is contingent upon exposure and potential harm from a hazard. It is at least in part, "a function of the character, magnitude, and rate of climate variation to which a system is exposed," (IPCC 2001, p.995). *Social vulnerability* is a function of the characteristics of a human system regardless of its physical exposure (Brooks 2003). Social vulnerability is, "the pre-event, inherent characteristics or qualities of systems that create the potential for harm or differential ability to recover," (Cutter et al. 2008).

Social vulnerability research generally seeks to reveal the underlying causes of vulnerability, including the role of cultural and political institutions or issues of resource distribution inequities, and then to identify opportunities to reduce vulnerability and enhance coping and adaptive capacity (Miller et al. 2010). Assessing the vulnerability of a place or the vulnerability of a community to a specific hazard would require the consideration of both biophysical and social vulnerability.

Often, researchers assessing the resilience of a system will also account for the biophysical vulnerability in terms of the exposure and potential disruptions of a hazard. For example, in their examination of socio-economic resilience to natural disaster, Hallegatte, Bangalor, and Vogt-Schilb (2015) account for "vulnerability" in terms of "the impact and damages [of a potential hazard] on the population and assets," (p. 4). Brooks (2003) acknowledges the broad equivalence of this interpretation of biophysical vulnerability with hazard risk, whereas social vulnerability is more likely to be assessed using a set of general predictive variables that are not hazard specific. These may include factors such as economic welfare, health and education status, and other inherent characteristics of a human system (Brooks 2003). When measuring resilience, the ability to reduce the impacts of, adapt to and recover from a disruption, some assessments may account for biophysical risk and the social vulnerability of the system.

There is definitely overlap in the characteristics that make social systems vulnerable and those that improve resilience (Enarson 2007, Cutter et al. 2008) When creating measures of these constructs, however, researchers need to carefully consider whether and in what ways each indicator influences the society's vulnerability and whether and in what ways each indicator influences the society's resilience, rather than assume that an indicator that shows higher levels of vulnerability necessarily shows low levels of resilience.

Cutter et al. (2014) clearly outline the need for distinct approaches to vulnerability and resilience in a quantitative assessment context:

> "The inability, thus far, to reconcile frameworks of disaster resilience and social vulnerability with available quantitative indicators hampers the ability to improve community-level disaster resilience. Composite quantitative measures are needed that would permit examination and/or comparison among places as to their present levels of both social vulnerability and disaster resilience, pointing decision-makers to possible targets for intervention and improvement," (p.66)

Through their analysis Cutter et al. (2014) demonstrate that while community disaster resilience is closely linked to social vulnerability, they are not simply the obverse of each other. The two constructions are distinct, "both conceptually and empirically, " (Cutter et al. 2014, p. 65).

3 Operationalizing Resilience

> "The urgency with which problems of disaster and emergency response, and hazard and risk mitigation, need to be solved is such that we cannot afford the luxury of producing theory for its own sake in the hope that some day it might somehow be useful," (Alexander 2013, p.1270-1271).

Different interpretations of the relationship between resilience and other associated concepts in DRR have made the concept of resilience difficult to operationalise (Alexander 2013). Conceptual fuzziness has limited efforts toward robust measurement, testing, and formalisation (Klein et al. 2003). There is a notable desire in the New Zealand policy and practice communities to move beyond academic debate surrounding resilience toward making resilience useful and useable for policy and management purposes. Practical approaches to making communities and infrastructure resilient are at the heart of the RNC-NSC.

A number of steps are important to operationalising resilience (i.e. moving from theory to meaningful action to enhance resilience). Steps to begin this move from theory to action include:

- Clearly define resilience for the system of interest
- Establish a vision for what resilience will help that system achieve (i.e. develop an operational definition and set of criteria)
- Identify important system drivers (people, resources, processes) and how they contribute to resilience.
- Identify observable components and behaviours to benchmark resilience and monitor the efficacy of interventions.
- Consider the context-specific features of the environment in which you will be operating. Are there features that may be interpreted or function differently here, compared to other places/systems?
- Consider the approaches to assessment that might be most appropriate in that context (e.g. top-down evaluations using centralised data-sources or bottom-up evaluations based on consultation and engagement)

Frameworks that identify the observable components and behaviours of resilience provide the first step toward operationalization. For example, Bahadur, Ibrahim, and Tanner (2010) derive ten characterisitcs of resilient social-ecological systems, which, they argue, help to operationalize the concept of resilience. The characteristics include: high diversity, effective governance and institutions, acceptance of uncertainty and change, community involvement, preparedness activities that accomodate change, social and economic equity, honoring social values and strcutures, acknowledging non-equilibrium dynamics, continuous learning, and adopting cross-scalar perspectives.

Once appropriate components are identified, it is possible to locate operational indicators that can be used to monitor the observable components of resilience and evaluate the efficacy of interventions.

Resilience measurements need to specify appropriate boudaries around the systems of interest. To measure resilience, "one needs to specify the time scale," (Carpenter et al. 2001, p.767) and the spatial scale because, the authors explain, resilience at one scale can be achieved at the expense of resilience at another ("cross-scale subsidies"). Additionally it is critical to specify the system state of interest (resilience of what) and the system disturbances of interest (resilience to what) (Carpenter et al. 2001).

4 Multi-capital Framework

The engineering (or *resistance*) and ecological approaches to resilience are insufficient for understanding and addressing the complex social-ecological challenge of building resilience to natural hazards (Stevenson 2014, Glavovic 2015). As we approach the broad mandate of making New

Zealand more resilient to hazards, it is essential to approach research and policy design from an integrated systems perspective.

4.1 Community Capitals Framework

The Community Capitals Framework (CCF) offers a systemic approach to community change (Emery & Flora 2006). The CCF is a theoretical and analytical tool designed to identify assets across a range of capitals that define the stocks and flow of resources within a community (Emery & Flora 2006; Flora, Flora, & Fey 2004).

The CCF was developed from foundational work on the Sustainable Livelihoods (SL) Framework developed initially by the Department for International Development (UK). The SL Framework and associated approaches sought to address the structural conditions that underlie pressing social issues (e.g. poverty) through assessments and interventions that recognise the interactions and inseparability of environmental, social, economic, and institutional aspects of societies (Ashley & Carney 1999).

In this model there are seven different components of community capital: natural, cultural, human, social, political, financial, and built (Emery & Flora 2006). Each of these is defined in **Table 3**.

Table 3: The Seven Capitals in the Community Capital Framework

Capital	Description
Natural	Assets that exist in a particular location, including weather, geographic isolation, natural resources, amenities, and natural beauty
Cultural	The way people "know the world" and how they act within it, as well as their traditions and language. Also referred to as institutional capital.
Human	The skills and abilities of people to develop and enhance their resources and to access outside resources and bodies of knowledge in order to increase their understanding, identify promising practices, and to access data for community-building. Human capital addresses the leadership's ability to "lead across differences," to focus on assets, to be inclusive and participatory, and to act proactively in shaping the future of the community or group
Social	The connections among people and organizations or the social "glue" or social credit that can make things happen.
Political	Political capital reflects access to power, organizations, connection to resources and power brokers. Political capital also refers to the ability of people to find their own voice and to engage in actions that contribute to the well being of their community.
Financial	Financial resources available to invest in community capacity-building, to underwrite the development of businesses, to support civic and social entrepreneurship, and to accumulate wealth for future community development.
Built	The physical infrastructure supporting these activities.

(Definitions from Emery & Flora 2006, p. 20-21)

Although each of these capitals is distinct, the CCF emphasises the interdependence, interaction, and synergy among the capitals (Gutierrez-Montes, Emery, & Fernandez-Baca 2009). Gutierrez-Montes et al. (2009) argue that when one capital is favoured over the others, the other resources are *decapitalised* and the system begins to spiral downward.

The shift in thinking from a deficit based approach to an assets based approach represented by the CCF, closely reflects the intellectual and policy shift from a vulnerability approach to a resilience approach in the hazards discourse. The CCF begins assessments by understanding what exists in a community, maps inventories of assets, and then considers strategies to build on those assets (Emery & Flora 2006). Through these approaches one can develop indicators of success (i.e. improvement of assets across the capitals) and potential areas of support (Emery & Flora 2006).

In the development of resilience assessments, the CCF offers a framework for shifting the dialogue from *aspects* (theoretical) to *assets* (applied) within a resilient system (Emory & Flora 2006). The CCF provides a coherent bridge from assessment to operationalization. Communities (in their various forms) can mobilize their assets to "build layers of resilience" (Glavovic 2015, p.62).

We are using the seven capitals to frame our approach to resilience indicator identification. For more on this see Deliverable 2: Multi-Capital Resilience Indicators Database (Short-Report) at the end of this report. This 'multi-capital' approach is reflected in the Treasury's Living Standards Framework and the Ministry of Civil Defence and Emergency Management's National Resilience Strategy (discussed in Section 5).

4.2 Holistic resilience, holistic improvement

It is worth noting that holistic approaches to resilience, which integrate understanding and interventions across the seven capitals, can improve the quality, equality, and functionality of the systems that compose our society. There are significant linkages between the concepts of sustainable livelihoods, "liveability" of society, and holistic resilience. It is beyond the scope of this report to explore this in greater depth; however, it is worth considering further the kinds of collaborative processes and policies to create a more resilient New Zealand.

4.3 Exemplars of best practice in holistic approaches to resilience

There are a number of research centres and Centres of Research Excellence that are leading current resilience conversations. As the RNC-NSC progresses it would be worth drawing upon research coming from these various forward thinking arenas. In some cases, researchers will pursue more involved collaborative relationships and joint initiatives. Such centres include:

- The International Centre of Excellence in Community Resilience based in Wellington, New Zealand
- IRDR International Centre of Excellence on Vulnerability and Resilience Metrics led by Dr. Susan Cutter and colleagues
- The Stockholm Resilience Centre
- The UN emBRACE: Building Resilience Amongst Communities in Europe initiative

There are many others, and it is imperative of RNC-NSC researchers to identify thought and practice leaders and build on their expertise.

5 Resilience Assessment Review

There are a number of frameworks for understanding and assessing resilience. In this section we outline the reasons for assessing resilience, identify observable resilience assets and drivers, and evaluate different types of resilience assessment tools and their relationship to resilience outcomes.

In a systematic review of community resilience assessment literature Ostadtaghizadeh et al. (2015) reporting the surprising finding that of the 675 papers the authors reviewed that had an identifiable reference to "community resilience," there were only 17 papers that actually attempted to measure community resilience. This led the authors to conclude:

> "This disparity provides a tangible indication of the proliferation in the use of the concept of 'community resilience,' the limited attention paid to its definition and systematic study, and the consequent need to identify a set of predictors that can inform the systematic assessment process," (Ostadtaghizadeh et al. 2015, p.13).

This recent study provides a persuasive argument for the advancement of systematic resilience assessment.

5.1 Why measure resilience?

> "In order to get a grip on it, one must be able to relate resilience to other properties that one has some means of ascertaining, through observation," (Martin-Breen & Andries 2011, p.11).

Resilience is a latent feature of complex social-ecological systems, and evolves through adaptive processes. It is not directly observable. There are potential pitfalls of trying to assign quantitative values to complex social issues. However, there is an important place for quantitative and systematic assessment processes (Risk Frontiers 2015). Combining quantitative and qualitative approaches can provide both systematic assessments and contextual understanding.

Prior and Hagmann (2014) provide a concise summary of the various objectives researchers and practitioners hope to achieve by measuring resilience. These reasons, which are geared toward risk managers and emergency management practitioners, are summarised in Table 4.

Table 4: Reasons for Measuring Resilience (Prior & Hagmann (2013), p.284-285)

Reason	Explanation
To characterise resilience	Given its multidimensionality, developing a measure for resilience can be a step towards characterizing resilience in a particular context. Establishing an adequate and usable measure of resilience first requires an articulation of the constituents of resilience, which is a valuable process in its own right.
To raise awareness	Methods of communicating the need to be resilient to at-risk entities can be assisted with an observable measure of resilience. Observations of resilience can help managers to direct resilience-related information to entities whose resilience is lower than some predetermined threshold.
To allocate resources for resilience	Measurement allows the quantitative comparison of resilience between entities and this becomes useful in the allocation of risk management resources. A [resilience index] could be used to argue that allocation of funds is made in a transparent manner.
To build resilience	Identifying entities with low resilience is important for managing disruption and its consequences. Knowing the extent of resilience can help risk management agencies to best direct their assistance measures. The development of resilience 'thresholds' can permit better resilience-related policy decisions. Additionally, without measuring resilience, it is difficult to gauge how resilience changes as a result of disruption or following the implementation of resilience-building practices or processes.
To monitor policy performance	An index could be used to assess the effectiveness of resilience-building policy through longitudinal comparisons of resilience in those entities targeted by the policy. To this end, the development of resilience-building policy should integrate the identification of policy goals and targets against which efficacy, or 'on-the-ground' outcomes, might be assessed.

In a research context, informing resource decisions and evaluating policy tend to be the priority areas used to justify the development of resilience measures, as well as informing which areas require further investigation and development. Measures that allow quantitative comparisons between entities (as specified by Prior and Hagmann (2013)) and those that identify the resilience of various assets within a complex system, can guide cost-benefit analyses and decisions about allocating time and financial resources to resilience interventions. Additionally, once interventions are made it is important to have a way of evaluating whether they are improving resilience and to what extent.

Yet, the first reason for measurement - *characterising resilience* through assessing its components and determinants - is an important foundation of all resilience research. If the research and practice communities cannot characterise resilience robustly, understand its drivers, system interactions, and complexities, then we cannot develop accurate criteria for evaluation or offer sound policy advice.

It is also important to note that there are benefits to purpose designed resilience assessment tools. Decisions makers and researchers will occasionally use available metrics designed for other purposes including deprivation, sustainability, vulnerability, and exposure as wholesale substitutes for resilience measures. Construct validity, or assessments that a tool is actually measuring the social construct that it is intended to measure, is an important element for designing assessments for any complex system. The process of tightly specifying the constructs assessed in the research not only increases validity of these measurements, but enhances reliability by outlining systematic measures to ensure the construct can be compared across a number of contexts (Yin 2009). We explore the idea of evaluating the quality and suitability of indicators in more detail in Deliverable 3: Heuristic Guide for Selecting & Tailoring Measurement Suites at the end of this report.

As the RNC-NSC research programme develops we will also be looking for opportunities to connect to resilience-building initiatives. For example, by identifying and testing mechanisms for interaction between science and the community in ways that can stimulate behaviour change or guide proactive policy interventions. We will then need to find ways to monitor whether these interventions do in fact enhance resilience.

5.2 Identifying Resilience Assets & Indicators

As a step toward assessing resilience, we have started the process of identifying assets or potential drivers associated with each capital that positively influence resilience.

The overarching goal of the Resilience to Nature's Challenge, as stated in the proposal is to:

> "…pursue a goal of transformative resilience, discovering and implementing new research-based solutions for our society, culture, infrastructure and governance to address factors that will enable New Zealand to thrive in the face of nature's challenges," (Jolly 2014, p. 5).

Therefore, we focus on identifying assets that, at least theoretically, can contribute to this goal of transformative resilience to nature's challenges (i.e. social-environmental hazards). These can include knowledge, skills, goods, structures, services, and processes that contribute positively to the elements of our meta-definition of resilience (respond post-event, maintain or recover essential functions, and adapt in a way that allows the system to learn or mitigate the negative impact of future events).

For more on resilience indicators and processes for indicator selection see:

- Deliverable 2: Multi-Capital Resilience Indicators Database (Short Report), and
- Deliverable 3: Heuristic Guide for Selecting & Tailoring Measurement,

5.3 Categories of assessment

Researchers and practitioners use a wide range of tools to assess and monitor hazards resilience. Here we provide a summary of three tools: indexes, scorecards (including surveys and compliance monitoring tools), and computational modelling (see Table 5).

The tools and techniques adopted depend on the assessors' desired outcomes, requirements, capabilities, as well the characteristics of the system. In addition to the tools described in Table 5, assessors may choose to combine quantitative measures with qualitative data to provide nuance and context. Mixed methods allow assessors to triangulate data, providing analytical rigour and richer interpretations (Prior & Hagmann 2013).

Each of these tools has useful applications and significant limitations. A national research agenda geared toward initiating transformative change should consider ways to combine these tools, qualitative and contextualised research, and community processes to provide an optimal suite for benchmarking and monitoring resilience and for initiating and guiding resilience policy and action.

The tools and techniques adopted depend on the assessors' desired outcomes, requirements, capabilities, as well the characteristics of the system. In addition to the tools described in Table 5, assessors may choose to supplement quantitative measures with qualitative data to provide nuance and context. Mixed methods allow assessors to triangulate data, providing analytical rigour and richer interpretations (Prior & Hagmann 2013).

The tools covered in **Table 5** focus mostly on tools developed by researchers, practitioners, and policy makers and deployed to assess communities, with varying degrees of co-creation or collaboration. Although it is out of the scope of this report it would be worth exploring the kinds of tools that may emerge from a community-led process, and how community narratives and practices can be captured to drive resilience evaluation and monitoring processes.

Table 5: Resilience Assessment Tools

Tool	Description	Benefits	Limitations	Examples
Indices	An indicator is a quantifiable variable that represents a characteristic of a system or phenomena. Indicators are combined to construct an index or composite indicator in order to capture the multidimensional nature of a system, while distilling it into a single metric (Tate 2011).	• Do not require primary data collection. • Facilitate standardized comparisons across space and time. • Helpful for identifying priority areas for resilience investment. • Local and expert knowledge can be included to inform the differential weighting of indicators (Barnett, Lambert, & Fry 2008). • Track spatial/temporal dynamics	• Often require large inputs of data • Data often needs to be aggregated from a number of sources, with different periodicity, spatial extent, and quality. • Compounding uncertainties can undermine the validity of the results (Barnett et al. 2008). • No built-in forecasting ability • Construction and results can be complex and difficult to effectively communicate.	• Baseline Resilience Indicators Model for Communities (BRIC) (Cutter et al. 2008, 2010) • Community Disaster Resilience Index (CDRI) (Peacock et al. 2010) • Rural Resilience Index (Cox & Hamlen 2014) • Economic Resilience Index (Briguglio et al. 2009) • Resilience Measurement Index for critical infrastructure (Petit et al. 2013)
Scorecards	Consist of a number of questions or assessment criteria, often with a set of scaled answers from which to select. The result can be a single 'score' or a collection of scores within a number of target areas.	• Provide 'current ' measures. • Relatively simple to administer (good for 'self-assessment' and engaging stakeholders) • Useful in areas that do not have regular or reliable data collection. • Facilitate standardized comparisons across space and time. • Flexible application at different scales and communities	• Time consuming and costly to deploy widely • Subject to multiple interpretations/ misinterpretation during self-assessments • Dimensions often limited to ease respondent burden.	• City Disaster Resilience Scorecard (UNISRD) • Risk and Resilience Scorecard (Ahorn, Burton, & Khazi 2014) • Organisational Benchmark Resilience Tool (Lee et al. 2013) • Community Resilience Disaster Scorecard – Australia (Arbon 2014)
Computational Models	Rendering of a system designed to help an observer to understand how it works and to predict its behaviour. Relationships are captured using a set of formulas or matrices (Sarokin 2015).	• Can simulate the potential impacts of events and the efficacy of different interventions. • Integrate specific hazard data/scenarios • Useful for capturing system complexities and dynamic changes	• End-users require specific knowledge of or training in software systems • Expensive to develop -restricted by available skills and resourcing • Data for robust empirical models is limited	• Community Resilience Modelling Environment (NIST 2015) • Regional Economic Resilience – CGE Model (Rose & Liao 2005) • Measuring the Economics of Resilient Infrastructure Tool (MERIT) (GNS 2014)

5.4 Scales of assessment

Resilience created, degraded, and maintained across several interacting systems at different scales (e.g. individual, household, community, region, ecosystem, nation). Understanding the manner in which various environmental and social factors operate and interact across different scales allows insight into the scales at which various levels of resilience are most pronounced (Burton 2015).

Systems collectively produce resilience through synergy and interaction; however, attempting to measure resilience at higher levels of aggregation can mask important disparities within a system. For example, measures of urban resilience such as the The Rockefeller City Resilience Framework (CRF) assess the co-production of resilience across the many systems that create healthy, highly functional, equitable, and adaptive cities. Yet, in all cities there is spatial and social stratification across most (if not all) of the resilience themes identified within the City Resilience Framework, such as mobility, health, and empowerment. As a result the CRF does include additional checks within the framework to capture connections at different scales, and to evaluate whether various systems within a city are inclusive and integrated.

This does not mean that we should defer to finer resolution resilience assessments. Rather we need to be aware that analyses at different scales are not necessarily reflective of the system as a whole or of the individual components. In addition to unequal distribution, in complex systems resilience at one scale may be achieved at the expense of resilience at another, what Carpenter et al. (2001) refer to as “cross-scale subsidies" (p.767). For example, to attain higher levels of national income or growth, governments may exploit particular communities or regions, depleting resources and increasing vulnerability at smaller scales. This is also true across time scales. Resilience to immediate threats may come at the expense of the long-term flexibility and adaptability of the system (another argument for maintaining a sustainability discourse in parallel to resilience discourse).

Finally, assessing resilience at different scales will require different methods. Data on individuals or businesses is often not systematically collected by government statistics agencies, and therefore resilience assessments at these levels often rely on primary data collection with populations of interest. Data availability and quality may vary greatly across different scales and for different systems of interest. For example, Cutter et al. (2014) found that capturing natural/ ecological resilience was very difficult at the national scale. All of these practical concerns make cross-scalar comparisons challenging, and researchers may need to investigate the scale at which various data sources are available before deciding how to structure their assessments.

5.5 Evaluating the Efficacy of Assessments Using a Maturity Model

We are still very much in the nascent stages of assessing resilience to disasters. There are new conceptual, empirical, and mechanistic assessment frameworks emerging regularly across a number of scales and systems. As researchers progress their work across the RNC-NSC and develop resilience assessment tools they may choose to build on existing frameworks or ‘translate’ tools developed in other contexts to their specific New Zealand-based system of interest.

There will not be a single best tool. We will need a suite of data collection and analysis tools including indicators and indexes that use secondary data, primary data collections tools such as survey to fill information gaps, and models and scenario tools to map paths forward.

In order to assist with this process, we have developed a prototype Resilience Assessment (RA) Maturity Model (Figure 2) to evaluate existing frameworks and provide pathways for further development. A maturity model is a staged structure, indicating levels to which specific processes, goals, or quality measures are assigned. The object being assessed using the model adopts and develops new processes and practices over time and moves on to the next level until the desired level is reached (Mingay 2002).

The evaluation criteria within the RA Maturity Model were derived from interviews with RNC-NSC stakeholders and the resilience literature. The evaluation criteria include:

- The theoretical foundation of the measure (i.e. resilience is clearly defined and distinct from other concepts)
- Whether the conceptual work on resilience has actually led to the development of an assessment tool.
- Whether that tool has been tested with empirical data and refined.
- Whether the assessments are operationalized to influence policy, inform decision-making, or prompt and guide resilience building interventions.
- Whether the model has been validated.

Validation is often the last step in the assessment (particularly index) construction process, and one that often receives little or no attention before the tool is deployed (Tate 2011). Validation is defined as a, "comparison of a model's predictions with the real world to determine whether the model is suitable for its intended purpose," (Mayer & Butler 1993, p.21). Models (referring to indices, computational models, and other assessment tools) require repeated validation across a number of contexts to confirm that they are indeed measuring the phenomenon they aim to measure (e.g. disaster resilience) (Bidwell 2011, Mayer & Butler 1993).

Because resilience is a construct that cannot be directly observed, validation requires proxies (Schneiderbauer & Ehrlich 2006). Robust validation is very difficult for models of resilience. A major difficulty stems from the fact that resilience indicators tend to be based on pre-disturbance conditions, while the validation proxies are based on post-event outcomes (Tate 2011). For example, to validate a model of disaster resilience, one may use proxies such as observed damage, the rate of population return, or the recapture rate of economic productivity. The outcomes of a specific disaster event are a weak proxy for the "multidimensional and multi-hazard" nature of resilience models (Tate 2011). Although progress is being made, validation is a significant challenge for creating robust resilience metrics.

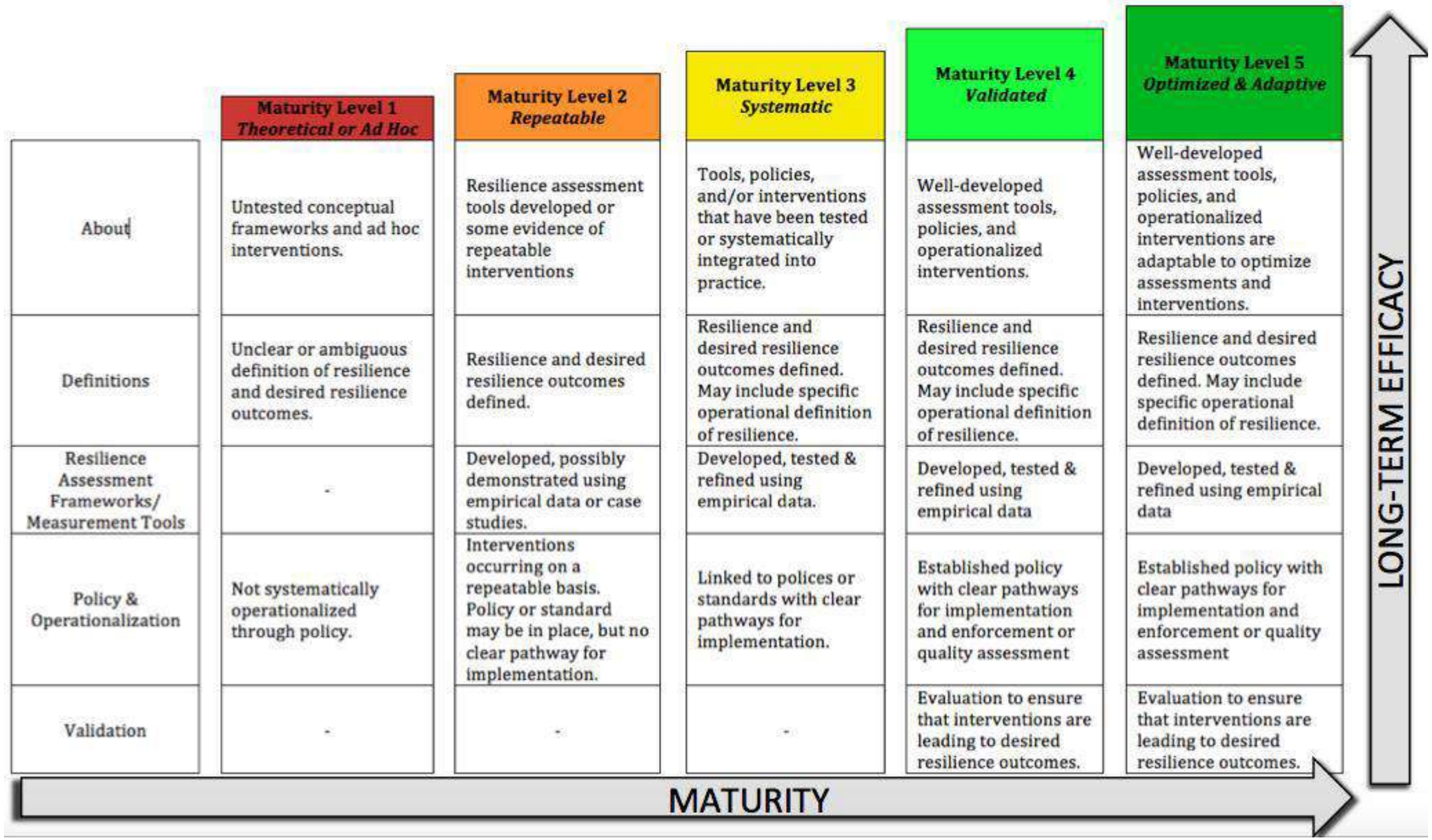
In this section we provide a preliminary review of a number of assessment frameworks and tools and give a rough indication of their maturity level. Of course, none of the tools were designed with this specific list of maturity criteria in mind. For some tool developers, whether or not their tool is operationalized in a way that influences policy or action is not important. However, in the context of the RNC-NSC the application and usability of the tool is important for fulfilling the ultimate goal of improving the disaster resilience of New Zealand.

5.5.1 Prominent Frameworks & Models

Cutter (2014) suggests that communities select a resilience measurement tool that meets the following criteria:

- Open and transparent
- Aligns with the community's goals and vision
- Measurements are:
    - simple, well documented
    - can be replicated
    - address multiple hazards
    - represent community's areal extent, physical (manmade and environmental) characteristics, and composition/diversity of community members
    - are adaptable and scalable to different community sizes, compositions, changing circumstances

NIST (2015), in their thorough review of resilience assessment frameworks, added to these criteria noting that they were particularly interested in community resilience metrics or tools that will, "reliably predict the physical, economic, and social implications (either positive or negative) of community decisions (either active or passive) made with respect to planning, siting, design, construction, operation, protection, maintenance, repair, and restoration of the built environment," (NIST 2015, p.1). As evidenced by this statement, 'community resilience' measures often include considerations of built, ecological, and institutional environments.



	Maturity Level 1 *Theoretical or Ad Hoc*	Maturity Level 2 *Repeatable*	Maturity Level 3 *Systematic*	Maturity Level 4 *Validated*	Maturity Level 5 *Optimized & Adaptive*
About	Untested conceptual frameworks and ad hoc interventions.	Resilience assessment tools developed or some evidence of repeatable interventions	Tools, policies, and/or interventions that have been tested or systematically integrated into practice.	Well-developed assessment tools, policies, and operationalized interventions.	Well-developed assessment tools, policies, and operationalized interventions are adaptable to optimize assessments and interventions.
Definitions	Unclear or ambiguous definition of resilience and desired resilience outcomes.	Resilience and desired resilience outcomes defined.	Resilience and desired resilience outcomes defined. May include specific operational definition of resilience.	Resilience and desired resilience outcomes defined. May include specific operational definition of resilience.	Resilience and desired resilience outcomes defined. May include specific operational definition of resilience.
Resilience Assessment Frameworks/ Measurement Tools	-	Developed, possibly demonstrated using empirical data or case studies.	Developed, tested & refined using empirical data.	Developed, tested & refined using empirical data	Developed, tested & refined using empirical data
Policy & Operationalization	Not systematically operationalized through policy.	Interventions occurring on a repeatable basis. Policy or standard may be in place, but no clear pathway for implementation.	Linked to polices or standards with clear pathways for implementation.	Established policy with clear pathways for implementation and enforcement or quality assessment	Established policy with clear pathways for implementation and enforcement or quality assessment
Validation	-	-	-	Evaluation to ensure that interventions are leading to desired resilience outcomes.	Evaluation to ensure that interventions are leading to desired resilience outcomes.

Figure 2: Prototype Resilience Assessment Maturity Model

The research undertaken as part of the RNC-NSC will cover a broad range of topics including resilience in specific systems of interest, such as infrastructure, social and organisational systems, and the economy, and across various communities through the urban, rural, edge[3], and Māori work streams. It is useful at this point in the process to investigate frameworks that cover a broad range of social-ecological and built environment indicators, and facilitate integration across the whole of the RNC-NSC (to the extent that it is possible). Some of the most holistic and integrated frameworks are constructed from the community systems perspective.

Characteristics of a Disaster Resilient Community

Twigg (2009) developed a guidance resource for government and civil society organisations working toward disaster risk reduction (DRR), climate change adaptation (CCA), and building community resilience. The resource is based on a framework developed by the UN International Strategy for Disaster Reduction (UNISDR): the Hyogo Framework for Action 2005-2015 (HFA). The five thematic areas within the resource include: governance, risk assessment, knowledge and education, risk management and vulnerability reduction, and disaster preparedness and response. These thematic areas are further subdivided into a larger number of resilience components and characteristics.

Twigg (2009) offers guidance for using the resource, "at various stages of project cycle management (e.g. for baseline studies, project design and evaluation), linked to other tools used in DRR projects and research (e.g. vulnerability and capacity analysis), for capacity building and advocacy, and for strategic planning," (p. 14). Although the guidance resource is not developed as a measure in itself, it has been used to ensure that resilience-benchmarking assessments are "sufficiently coherent and wide-ranging to cover all relevant issues," (Twigg 2009, p.22). Assessments and interventions associated with this resource have been tested and refined using case studies.

Seismic Resilience of Communities Framework/ Resilient Infrastructure Principal Features

Bruneau et al. (2003) developed a conceptual framework and quantitative measures for the seismic resilience of communities. In the framework resilient systems should be able demonstrate three qualities: reduced failure probabilities, reduced consequences from failures, and reduced time to recovery.

Table 6: Properties of resilient systems (Tierney & Bruneau 2007)

Component	Description	Criteria
Robustness	Maintaining its functioning and performance in times of disturbances/ disasters	Extensiveness of emergency operations planning
Redundancy	Extent to which organizations or specific units are substitutable, i.e. capable of satisfying functional requirements	Presence of alternate sites for managing dis- aster operations
Resourcefulness	Diagnose and prioritize problems, initiate solutions by identifying and mobilizing material, monetary, informational, technological, and human resources	Ability to be flexible, to improvise, innovate, expand
Rapidity	Restore functionality in a timely way, containing losses and avoiding disruptions	Time needed to regain functionality

From Birkmann et al. (2012) Systemaatization of Different Concepts, Quality Criteria, and Indicators. *emBRACE Working Paper Deliverable 1.2: Building Resilience Amongst Communities in Europe*.

[3] Edge refers to "communities living perilously at the 'edge' of coastlines, rivers and mountains that otherwise face a highly uncertain future, and transformative Māori research," (Jolly 2014, p.5).

The quantitative indicators are built on identifying and measuring the underlying dynamic properties of the four dimensions of community resilience—technical, organisation, social, and economic (TOSE). These properties include robustness, redundancy, resourcefulness, and rapidity (defined in Table 6).

By incorporating Resourcefulness into resilience, a system, building, or structure can recover quicker (Petit et al., 2012). Rapidity refers to the speed with which disruption can be overcome and functionality restored (McDaniels et al., 2008). Rapidity is important for resilience of buildings so a predictive analysis of how multi-hazards might affect a building, structure or system, incorporating rapid restoration plans is recommended.

Many authors view robustness as one of the key features of resilience referring to Robustness as ‘‘the ability…. to withstand a given level of stress…without suffering degradation or loss of function’’ (McDaniels et al., 2008) or maintaining the system or network performance when it faces external, unforeseeable disturbances (Carlson and Doyle, 2002). Redundancy is seen as another feature of resilience (Bruneau et al. (2003); De Bruijne and Van Eeten (2007).

O'Rourke, (2007) suggests redundancy is a feature that allows for alternative choices, decisions and substitutions in the case of disaster or under pressure. Resourcefulness is seen as the ability to manage the impacts of the crisis on the system or building, including the ability to organize needed resources and services in a predicament (O'Rourke, 2007).

This work has also been very influential for understanding and modelling infrastructure resilience. Costello, Sajoudi, and Wilkinson (2014) assessed resilient infrastructure definitions concluding that resilient infrastructure considered at least one of the following themes: the ability to absorb shock; the ability to recover the functionality of infrastructure after a disaster, or sudden shock; and the ability to operate to at least a basic or reduced capacity.

Eight principal features are used to define building and infrastructure resilience. Some of these features are complimentary, some are overlapping. Building on Bruneau et al. (2003), O’Rourke (2007) lists the four pillars of resilience as Robustness, Redundancy, Resourcefulness and Rapidity initially as a means of understanding resilience in communities or organisations.

The four other commonly referred to features of resilience are; capacity, flexibility, tolerance, and cohesiveness. These features are seen as having overlapping characteristics with the four above features. Capacity is similar to Robustness in that capacity is seen as the ability to withstand disturbances (Mendonca and Wallace, 2006). However, capacity also incorporates redundancy, to allow for infrastructure to be able to absorb additional demand in a time of crisis.

Flexibility is the system’s ability to restructure or reorder itself in response to external changes or pressures (Woods, 2006), although this may be more applicable to networks rather than buildings. Tolerance allows the assessment of how well a system behaves near its boundary – whether the system gracefully degrades as stress/pressure increases or collapses quickly when stress/pressure exceeds adaptive capacity (Woods, 2006) and should be considered as important in avoiding sudden collapse. Finally, Jackson (2009) asserts that cohesiveness between the various parts of the infrastructure or building needs to be incorporated into resilience as a means of understanding how well each sub-part of the infrastructure or building relates to the other parts.

More recently the concept of ‘safe-to-fail’ design (Snowden 2006; Park et al 2013) has been used to understand resilience, which would require planned, predictable modes of failure that have been anticipated and designed for.

A checklist of relevance of the above key features of resilience to a particular structure or building could assist as a rudimentary test for resilience. However, further developments in resilience assessments for buildings need to incorporate a robust scientific approach to resilience features.

Cimellaro, Reinhorn, and Bruneau (2010) and others have further developed the quantitative measures proposed in Bruneau et al. (2003), through mechanistic and empirical modelling for engineered and organisational systems. The framework, which we refer to as the *Analytical Quantification of Disaster Resilience (AQDR)* provides a quantitative definition of resilience, “using an analytical function that may fit both technical and organizational issues,” with specific application to the assessment of health care facility resilience (Cimellaro et a. 2010).

The AQDR presents a highly technical and specific interpretation of resilience for engineered systems and organisations. Seismic resilience is calculated by combining potential economic losses, casualties, recovery time, fragility functions, and other factors to reflect functionality over time.

Functionality curves (as pictured in **Figure 3**) are also informed by mathematical representations of rapidity, robustness, redundancy, and resourcefulness, which are represented as technical and organizational changes that can enhance the resilience of the system.

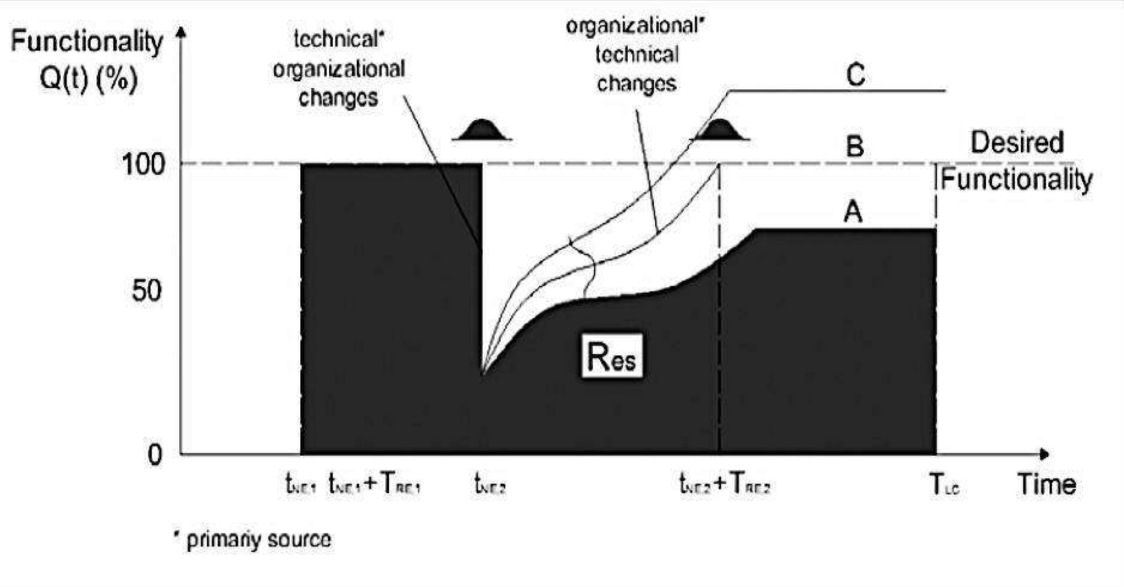


Figure 3: Schematic representation of disaster resilience (from Cimellaro et al. 2010, p.3642)

The analytical function of resilience is treated as a "unique decision variable," (Cimellaro et a. 2010, p. 3640), to guide investment and strategic decision-making. The outputs of these functions have specific applications to seismic planning to minimise casualties and economic losses from failures of engineered and other critical systems such as health care facilities. The AQDR and other similar approaches that operationalise Bruneau et al.'s (2003) Seismic Resilience of Communities Framework are designed for robust expert application and interpretation for specific system evaluations. They are less useful for all-hazards, society-wide resilience assessments, public communication, and informing broader social policies.

Baseline Resilience Indicators for Communities

Cutter et al. (2008) developed the disaster resilience of place (DROP) model, which linked vulnerability, adaptive capacity, and resilience and the associated variables that contribute to community resilience. Cutter et al. (2010) and Cutter, Ash, and Emrich (2014) built on the conceptual foundation of the DROP model to develop a quantitative index: Baseline Resilience Indicators for Communities. The index assesses six capitals or domains of resilience identified in the DROP model (social, economic, institutional, infrastructure, ecological, and community capital). A total of 49 variables were used to analyse community resilience in the continental US (Cutter et al. 2014). Each of the resilience subcomponents contains seven to eight variables.

The latest iteration of this index (discussed in Cutter at al. 2014) utilises data from 30 different sources. The selected datasets are almost all free and open source, in order to facilitate replication of the measures and enhance the usability and transferability of the tool.

The index was further developed and validated against Hurricane Katrina community recovery proxies by Burton (2014). The study found that the amount of damage sustained is the strongest predictor of achieving a full recovery in the long-term, followed by social and then economic factors of resilience. Correlations of other factors are ranked in the following order: infrastructural indicators, community capacity indicators, institutional indicators and environmental indicators.

Table 7 lists the indicators selected for the latest version of the tool (see Cutter et al. 2014 for full indicator descriptions and derivation information).

Table 7: Resilience indicator sets used in the BRIC model

Resilience concept	Indicator	Resilience concept	Indicator
Social Resilience	Educational attainment equality Pre-retirement	Institutional Resilience	Mitigation spending
	Pre-retirement age		Flood insurance coverage
	Transportation		Jurisdictional coordination
	Communication capacity English		Disaster aid experience
	English language competency		Local disaster training
	Non-special needs		Performance regimes-state capital
	Health insurance		Performance regimes-nearest metro area
	Mental health support Food		Population stability
	Food provisioning capacity Physician access		Nuclear plant accident planning
Economic Resilience	Homeownership		Crop insurance coverage
	Employment rate	Housing/Infrastructural Resilience	Sturdier housing types
	Race/ethnicity income equality		Temporary housing availability
	Non-dependence on primary/ tourism sector		Medical care capacity
	Gender income equality		Evacuation routes
	Business size		Housing stock construction quality
	Large retail-regional/national geographic distribution		Temporary shelter availability
	Federal employment		School restoration potential
Community Capital	Place attachment - not recent immigrants		Industrial re-supply potential
	Place attachment – native born residents		High speed internet infrastructure
	Political engagement	Environmental Resilience	Local food suppliers
	Social capital-religious organizations		Natural flood buffers
	Social capital – civic organizations		Efficient energy use
	Social capital – disaster volunteerism		Pervious surfaces
	Citizen disaster preparedness and response skills		Efficient water use

City Disaster Resilience Scorecard

IBM and AECOM designed the City Disaster Resilience Scorecard for the United Nations International Strategy for Disaster Reduction (UNISDR). The scorecard is based upon the UNISDR's Making My City Resilient Campaign "Ten Essentials"; it is designed as a local self-assessment tool, "to provide a single integrated perspective on a city's total disaster resilience posture, and on the connections between the many different aspects of disaster resilience, while also identifying gaps in plans and provisions," (UNISDR, n.d.). The scorecard consists of 80 assessment points (questions) the answers to which are based on a 0-5 scale. The questions are divided among the 10 essentials categories, so assessors can receive a separate score for each category, which allows them to identify areas of strength and weakness. Answers to the scorecard questions are determined by interviews and by examination of available secondary data sources.

The UNISDR used the Scorecard as part of their “My City is Getting Ready!” campaign, which aimed to support implementation of resilience interventions, facilitate connections between cities, stakeholders, and private sector partners (UNISDR 2012). Like all scorecard approaches, it as much a benchmark and reporting tool as it is a tool for facilitating communication and engagement. It does not appear to have been robustly statistically validated. Unfortunately, as with many assessment and engagement tools, there are no clear pathways for facilitating change or for continued monitoring of resilience after the City Disaster Resilience benchmarking is completed.

Community Resilience Index

Norris et al. (2008) develop a resilience framework based on four primary sets of adaptive capacities: economic development, social capital, community competence, and information and communication. These adaptive capacities are defined as resources (i.e. capitals) with dynamic attributes (robustness, redundancy, resourcefulness, and rapidity) (Bruneau et al., 2003). Under each of these resources are indicator themes, in total 21 indicator themes are proposed (Norris et al. 2008).

Sherrieb, Norris, and Galea (2010) operationalized the resilience framework though the Community Resilience Index. Sherrieb et al. (2010) validated the indicators against a well-established index of social vulnerability (Cutter et al. 2003) and survey data on collective efficacy. Ten indicators for economic development and seven indicators for social capital were identified for inclusion in the index. This index was empirically tested and refined using county-level data for the U.S. state of Mississippi (Sherrieb et al. 2010), and adapted into a survey and integrated into the Communities Advancing Resilience Toolkit (CART) and applied in schools across the US (Sherrieb et al. 2012).

5.5.2 Frameworks & Models Applied in New Zealand

These frameworks are presented on an increasing scale of management, starting with an infrastructure system measurement framework, moving to models designed to work at the municipal or territorial authority level, to the national policy and international strategy levels.

Framework for Measuring Transport System Resilience

In 2013 and 2014 AECOM developed a qualitative resilience framework for the New Zealand Transport Authority (NZTA) (Hughes & Healy 2014). The framework is based on six principles within two dimensions of resilience:

- Technical principles: robustness, redundancy, and safe-to-fail
- Organisational principles: change readiness, leadership and culture, and networks.

Each of these principles is accompanied by assessment criteria. Each criterion is scored and can then be aggregated and weighted to generate a system resilience score from 4 (very high resilience) to 1 (low resilience). The framework differs slightly based on the assessment “context,” defined relative to the disruption characteristics (all hazards or specific hazards including shock or stress events) and the scale of the system being assessed (i.e. region, network, or asset).

The assessment criteria are based on a series of measurement scales with qualitative descriptions. The user applying the measurement uses expert judgement to score each criteria based on this scale. The example in **Figure 4** below illustrates how this works.

Weights for each principle are also determined by the user, and must add up to 100% within each dimension (technical and organisational).

The developers of the assessment tool emphasise that this is a decision support assessment tool. It should either be accompanied by a system criticality (i.e. social, economic, and strategic importance) assessment or for all-hazards approaches, or a risk assessment detailing potential hazards and failure probabilities for a hazards specific approach.

The tool is geared toward practicality and ease of use. It does, however, require operator knowledge of the assets and relevant organisations (Hughes & Healy 2014). A large-scale assessment using this tool would require significant expert input and resources. It has not yet been tested and refined using real disruption scenario data and will likely continue to develop with further practical application.

ROBUSTNESS						Weighted robustness score	2.3
Category	Measure	Measurement	Measurement scale	Individual score	Category average	Weighting (%)	Weighted score
Structural	Maintenance	Processes exist to maintain critical infrastructure and ensure integrity and operability – as per documented standards, policies & asset management plans (eg roads maintained, flood banks maintained, stormwater systems are not blocked. Should prioritise critical assets as identified.	4 – Audited annual inspection process for critical assets and corrective maintenance completed when required. 3 – Non-audited annual inspection process for critical assets and corrective maintenance completed when required. 2 – Ad hoc inspections or corrective maintenance completed, but with delays/backlog. 1 – No inspections or corrective maintenance not completed.	3.0	2.8	33.33%	94.4
	Renewal	Evidence that planning for asset renewal and upgrades to improve resilience into system networks exist and are implemented.	4 – Renewal and upgrade plans exist for critical assets, are linked to resilience, and are reviewed, updated and implemented. 3 – Renewal and upgrade plans exist for critical assets and are linked to resilience, however no evidence that they are followed. 2 – Plan is not linked to resilience and an ad hoc approach is undertaken. 1 – No plan exists and no proactive renewal or upgrades of assets.	4.0			
	Design	Percentage of assets that are at or below current codes	4 – 80% are at or above current codes 3 – 50-80% are at or above current codes 2 – 20-50% are at or above current codes 1 – Nearly all are below current codes	3.0			
		Assessment of general condition of critical assets across region	4 – 80% are considered good condition 3 – 50-80% are considered good condition 2 – 20-50% are considered good condition 1 – Nearly all poor condition	3.0			
		Percentage of assets that are in zones/areas known to have exposure to hazards	4 – <20% have some exposure to known hazards 3 – 20-50% are highly exposed, or >50% are moderately exposed 2 – 50-80% are highly exposed 1 – 80% are highly exposed to a hazard	2.0			
		Percentage of critical assets with additional capacity over and above normal demand capacity	4 – 80%+ of critical assets have >50% spare capacity available 3 – 50-80% of critical assets have >50% available 2 – 20-50% of critical assets have >50% spare capacity 1 – 0-20% have spare capacity.	2.0			

Figure 4: Resilience measures for the 'robustness principles' in the Transport Resilience Framework (from Hughes & Healy 2014, p.42)

Adaptive Capacity/ Resilience Model

Drawing on over a decade of empirical research on social-cognitive disaster preparedness, vulnerability, and resilience (e.g. Paton (1996), Paton & Johnston (2001), Paton, Millar, & Johnston 2001), Paton (2007) proposed a general resilience model for New Zealand, comprised of personal, community, and institutional indicators. The first version of the model was derived from the survey responses of 400 residents in and around the city of Auckland (297 surveys were ultimately used for the preliminary model development due to missing data).

Structural equation modeling revealed eight factors that influenced community disaster resilience:

- Person-level: action coping, positive outcome expectancy, negative outcome expectancy, intentions
- Community-level: community participation, ability to articulate community problems
- Institution-level: empowerment and trust

Data on the eight factors can be combined into a composite measure and assessed on a scale of 1-10 for place-based comparisons. The tool developers selected variables for the model if: they previously demonstrated a capacity to predict resilience to hazards or had been used with New Zealand populations, and were open to change through the emergency planning process and related interventions (Paton 2007).

Analyses based on the eight resilience factors demonstrate that the factors are interrelated, but do not overlap enough to present issues of covariance (Figure 5).

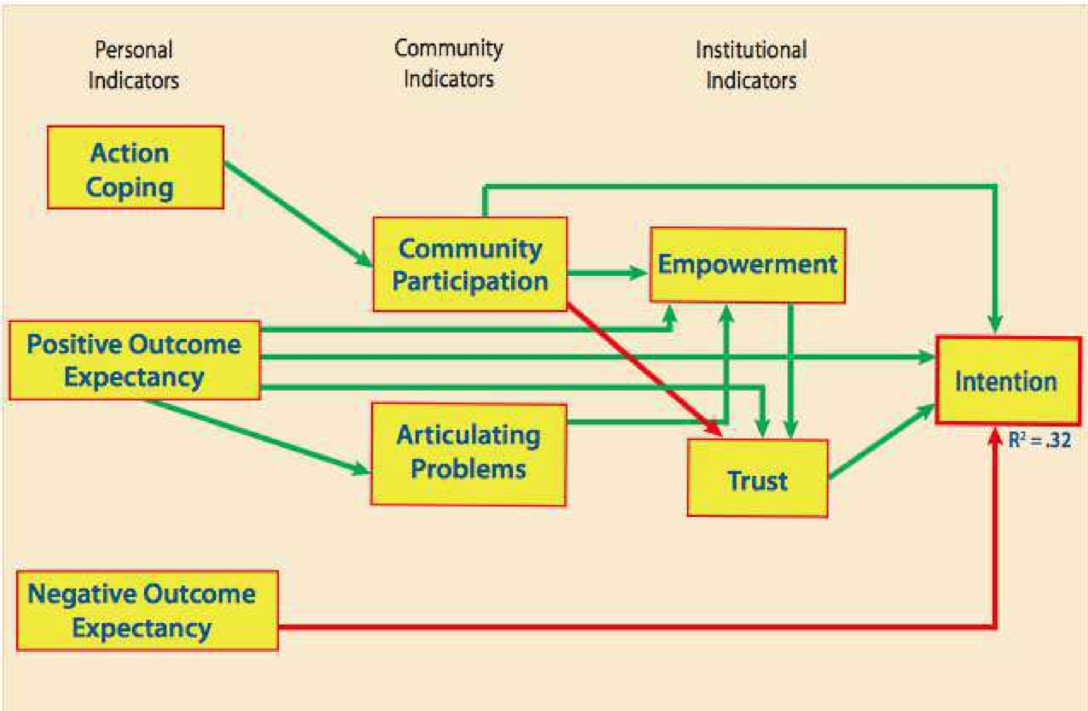


Figure 5: Resilience model, illustrating the linkages between indicator types as tested in Auckland pandemic scenario (from Paton 2008 in Daly et al. 2009, p.17)

Many of the questions that represent each item refer to a specific type of hazard. For example, participants rated their level of agreement with statements such as "Preparing for a volcanic eruption will improve the value of my property," to represent outcome expectancy measures (Paton 2007, p29). Application of a modified survey using other hazard scenarios, such as pandemic (Paton 2008) and earthquake (Paton & Johnston 2008) validated the model structure for application across multi-hazard environments. It is unclear whether this tool can assess inherent resilience to unknown risks.

The model does not incorporate differential risk exposure. Paton (2007, 2008) instead emphasizes that assessing resilience must occur in a context in which, "the potential demands associated with hazards must be the same for all participants," (Paton 2008, p.1). The validation studies are therefore limited to hypothetical situations in which risk distribution is relatively equal across a population (e.g. pandemic).

The model has not yet been validated using ex-ante data to determine whether the factors actually enhance post-disaster outcomes for individuals or communities. However, using empirical data collected following the 2010/2011 Canterbury earthquakes, Paton et al. (2015) did examine, "what actions and competencies would be required to [influence readiness to] cope with, adapt to and recover from direct and indirect earthquake hazard consequences," (p.6). People recovering from the earthquakes were asked in focus groups and interviews to identify actions that did or could have increased their readiness. Thematic analysis revealed a number of "functional readiness categories" and predictors of each category (Paton et al. 2015, p. 3). The authors then examined whether the individual-level, community-level, and institutional-level characteristics and processes (identified above) were predictors of three different functional readiness categories: survival preparedness, community relationship preparedness, and community-agency relationship preparedness. Most of the characteristics and processes were statistically significant predictors of at least one of the functional readiness categories with varying degrees of strength. The factor analysis did not support items within the psychological preparedness category, including coping style (action coping) and self-efficacy. The authors recommend further assessment of these items.

Canterbury Wellbeing Index

The Canterbury Earthquake Recovery Authority (CERA), in collaboration with a number of government agencies, has developed the Canterbury Wellbeing Index (CWI). The index was developed through inter-agency consultation and an international best practice literature review to develop a practical social wellbeing index for recovery from an earthquake event. This index is used to track social recovery in Christchurch following the 2010/2011 earthquakes in the region.

In addition to the 28 agencies consulted during the development of the social indicators that make up the index, best practice advice was provided by Christchurch District Health Board literature review 'Designing indicators for measuring recovery from disasters' (Bidwell, 2011).

Indicators withing the CWI are populated with data from secondary datasets and supplemented by a bespoke wellbeing survey of local residents. The CERA Wellbeing Survey (CWS) gathers wellbeing data from representative samples of the population affected by the earthquake sequence (Morgan et al. 2015).

First published in 2013, the Canterbury Wellbeing Index is updated twice a year (in April and September). The CWI enables evidence-based decision making and intervention design. It also provides the community with accurate and up-to-date information about the progress of social recovery. Going forward, the data gathered using the CWS will provide a robust longitudinal dataset for future research (Morgan et al. 2015).

The CWS provides a number of unique advantages, that provide a useful example for action oriented research:

> "The sampling frame can be tailored to the particular need, and surveys allow… sufficient numbers for disaggregation by characteristics of particular interest (for example geo-graphical sub-region, age, ethnicity and socioeconomic status). Surveys can also be used to address questions specific to the event and to the stage of recovery, including measuring positive aspects such as quality of life, resilience, and social connectedness. Representative samples can address the high mobility of post-disaster populations by providing an up to date sample at a given point in time," (Morgan et al. 2015, p.3-4).

The Canterbury Wellbeing Index is comprised of indicators grouped into seven themes and a number of sub-themes (Table 8). Where possible, indicators are tailored to the geographic boundaries of Christchurch City, Selwyn District, and Waimakariri District Councils. CERA regularly aggregates data across local and national Government agencies and coordinates to ensure that emerging social wellbeing trends are picked up and the information is provided to those that can facilitate responses.

The Wellbeing Index is an excellent example of an assessment and monitoring tool with direct links to policy interventions and actions. There is potential to modify this model to provide pre-event monitoring in a way that could enhance the absorptive capacity of a community and create faster and more efficient recovery processes.

Table 8: Themes assessed as part of the Canterbury Wellbeing Index

Themes	Sub-theme
Knowledge and skills	Participation in education Educational achievement: NCEA Level 2 pass rate
Economic wellbeing	Employment outcomes Household income
Housing	Housing affordability and availability
Health	Keeping well and having access to health services Mental wellbeing Risk factors
Safety	Offending patterns Child abuse and neglect
Social connectedness	People participate in and attend the arts Sports participation Household are prepared for civil defence emergencies Social connectedness
Civil participation	Civil participation
People	Population

The Quality of Life (QoL) survey initiated by Local Government New Zealand and run for a number of years across six cities in New Zealand, provides a pre-earthquake baseline of wellbeing data. The CWI includes QoL wellbeing questions, which both enables longitudinal comparisons and the ability to compare trends with the other five cities in the QoL sample (Morgan et al. 2015). The CWI, however, is a practical tool for the Canterbury population and is not designed to allow comprehensive comparisons across different contexts.

The CWI was also not designed as a predictive tool, and therefore is not being validated in terms of its ability to predict better or worse outcomes for those experiencing disruptions. However, from the second iteration of the survey, CERA used a wellbeing scale that was validated using robust psychometric anlyses (Morgan et al. 2015). The tool has also been assessed for interdependency and collinearity issues, with findings indicating that these issues are unlikely to pose a significant problem in ongoing multivariate analyses (Morgan et al. 2015).

Build Back Better Framework

Former US President Bill Clinton's (2006) "Key Propositions for Building Back Better" was the earliest known official document to be published which attempted to provide a comprehensive guideline for implementing BBB practices in post-disaster environments. The report was based on and aimed at the Indian Ocean Tsunami disaster. Clinton (2006) introduced ten propositions for BBB. Clinton's propositions were (Clinton 2006): Proposition 1: Governments, donors and aid agencies must recognize that families and communities drive their own recovery. Proposition 2: Recovery must promote fairness and equity. Proposition 3: Governments must enhance preparedness for future disasters. Proposition 4: Local governments must be empowered to manage recovery efforts, and must devote greater resources to strengthening government recovery institutions, especially at the local level. Proposition 5: Good recovery planning and effective coordination depend on good information. Proposition 6: The UN, World Bank, and other multilateral agencies must clarify their roles and relationships, especially in addressing the early stages of a recovery process. Proposition 7: The expanding role of NGOs and the Red Cross/Red Crescent Movement carries greater responsibilities for quality in recovery efforts. Proposition 8: From the start of recovery operations, governments and aid agencies must create the conditions for entrepreneurs to flourish. Proposition 9: Beneficiaries deserve the kind of agency partnerships that move beyond rivalry and unhealthy competition. Proposition 10: Good recovery must leave communities safer by reducing risks and building resilience.

The ten building back better propositions published by Clinton (2006), attempt to categorise each of the key aspects all communities should address when rebuilding from a natural disaster, while also being practical and versatile for rebuilding from a range of natural disasters. Mannakkara and Wilkinson (2014) re-conceived a new holistic Build Back Better framework, with six key principles, two each for the three key considerations of natural disaster rebuilding; Risk Reduction, Community Involvement and Implementation underpinned by monitoring and evaluation. Figure 3 shows the basis of the Build Back Better framework developed by Mannakkara and Wilkinson (2014).

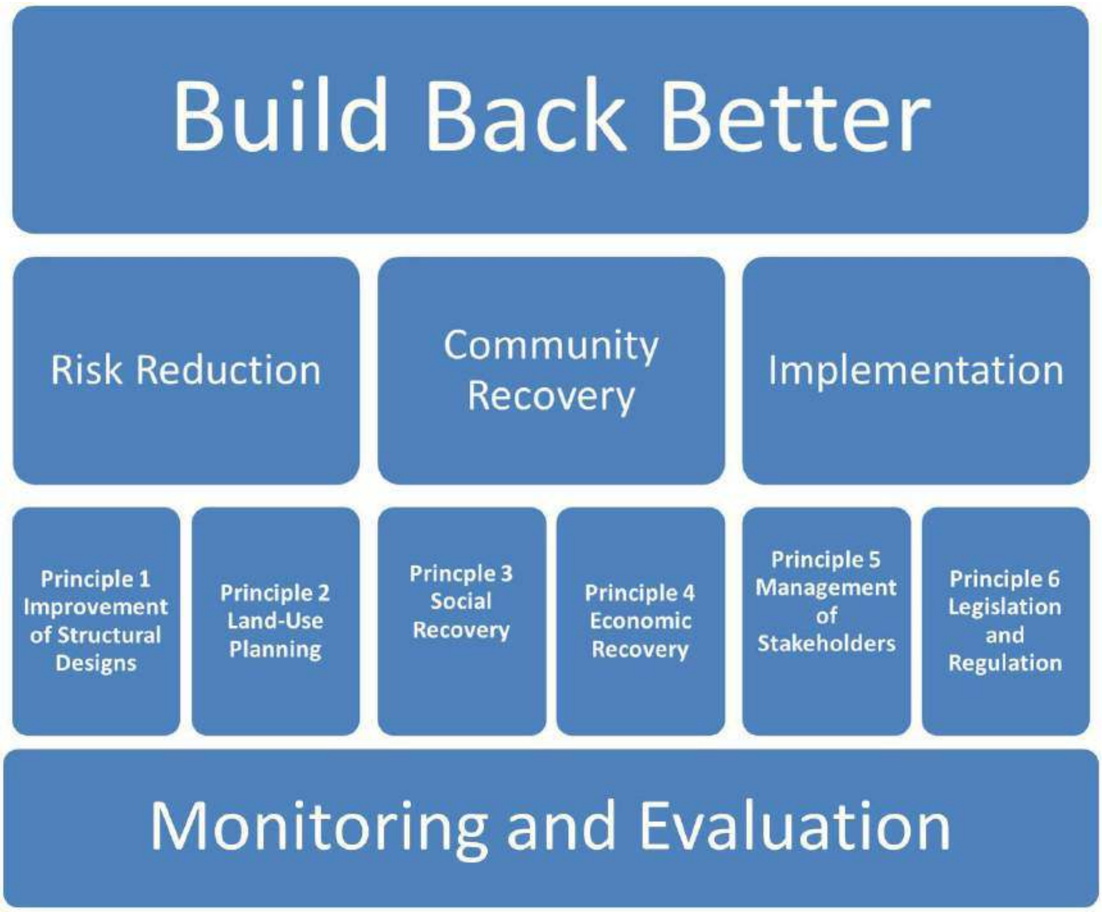


Figure 6: Build Back Better Framework (from Mannakkara & Wilkinson 2014)

Risk Reduction identifies all actions taken towards reducing disaster risks in communities to improve the physical resilience in the built environment. The two primary ways of risk reduction is through improving structural designs and through better land-use. Community Recovery portrays the initiatives put in place to deal with community-related aspects of recovery. Supporting psychosocial recovery and economic recovery of affected communities have been identified as essential for building back better. Implementation refers to the means by which Risk Reduction and Community Recovery practices can be implemented effectively and efficiently. Better management of the large number of stakeholders that often become involved in reconstruction and recovery projects is necessary to improve efficiency and performance. Monitoring and Evaluation is applied across the first three BBB categories and throughout the recovery process. The BBB framework is not a quantitative assessment tool, but could be shaped into a checklist or scorecard to guide resilience-building action in a post-disaster scenario. Basset (2015), for example, assessed the reconstruction of Christchurch's horizontal water infrastructure following the 2010/2011 Canterbury earthquakes, using a modified version of the BBB framework.

The City Resilience Framework

The City Resilience Framework (CRF) was developed by ARUP for the Rockefeller Foundation (ARUP 2014a). The CRF is based on four essential dimensions of urban resilience (the outer ring of Figure 7) including health and wellbeing, economy and society, structure and environment, and leadership and strategy. The framework covers: 1) the seven qualities of resilient cities, 2) the eight city functions that are critical to resilience, and 3) the 12 key themes that need to be addressed in contribute to city resilience.

The developers of the framework interpret the seven qualities of a resilient city through the implementation of resilience interventions and the maintenance and effective functioning of city systems. They add to this by introducing a performance-based approach to resilience, highlighting the organic life of urban systems that have functional characteristics through which they enact resilience.

The framework is based on enhancing overall performance and on flexibility and adaptability in contrast to risk management which relies on knowledge about specific hazards and their possible consequences. The framework is aligned with systems based approaches to urban problem solving (as opposed to asset-based approaches) to ensure that components within a system are accounted for as well as the connections between those components and connections at different scales.

The CRF is intended to serve as the basis of a City Resilience Index (CRI), with approximately 48-54 sub-indicators and 130-150 variables or metrics. The CRF is currently informing policy and resilience interventions in New Zealand through the 100 Resilient Cities programme run by the Rockefeller Foundation in collaboration with the cities of Christchurch and Wellington. Ultimately, the CRI will provide a quantitative and comparable metric, but the CRF does not provide this function (ARUP 2014b).

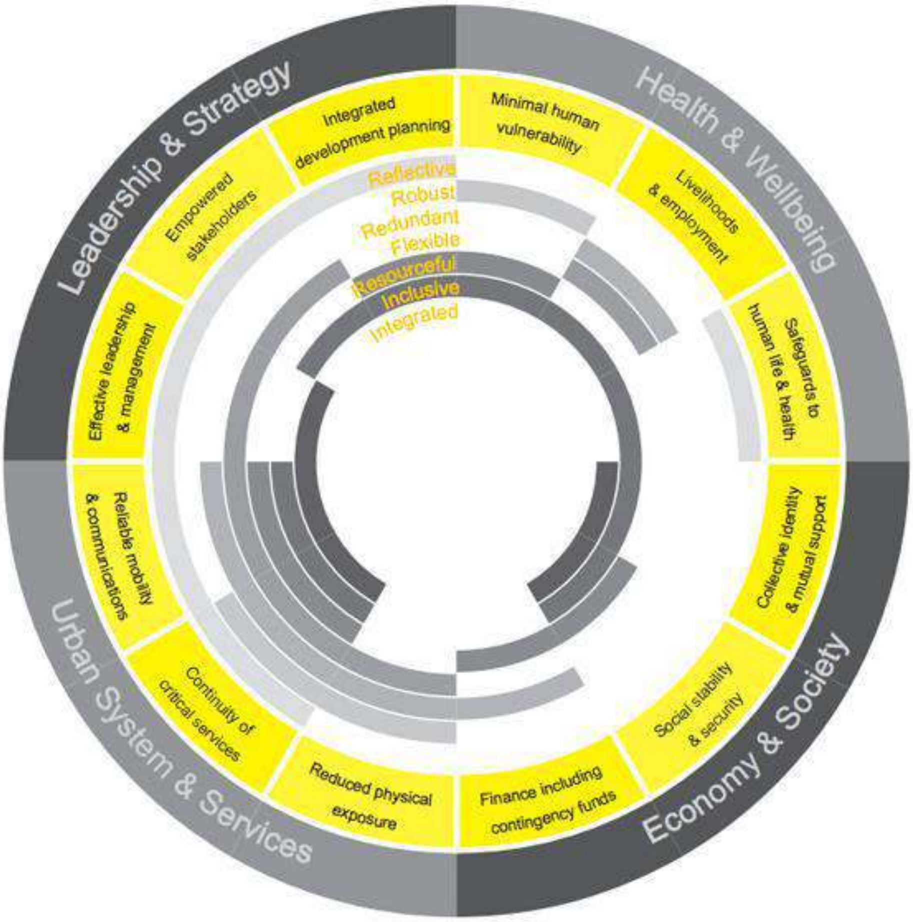


Figure 7: Rockefeller Resilient Cities Framework (ARUP 2014b)

The Living Standards Framework

The New Zealand Treasury released the Living Standards Framework (LSF) in 2011. The LSF was designed to capture a more complete view of the values that underpin the Treasury's advice and policy decisions – notably that the New Zealand Government should be focused on improving the lives of residents across a number of dimensions, not just material wealth (e.g. GDP growth).

The LSF was built upon five key principles:

- "There is a broad range of material and non-material determinants of living standards beyond income and Gross Domestic Product.
- Freedoms, rights and capabilities are important for living standards
- The distribution of living standards across different groups in society is an ethical concern for the public, and a political concern for governments
- The sustainability of living standards over time is important, so analysis of policy needs to weigh up short-term and long-term costs and benefits.
- Measuring living standards with subjective measures of wellbeing provides a useful crosscheck of what is important to individuals," (Karacaoglu 2012, p.4).

These principles are captured in the framework (Figure 8), as a series of stocks and flows. The stocks are capital based and include: financial and physical, human, social, and natural capital. The flows include actions, amenities, and resources that facilitate economic growth, sustainability, equity, social capital, and reduce macro-economic vulnerability.

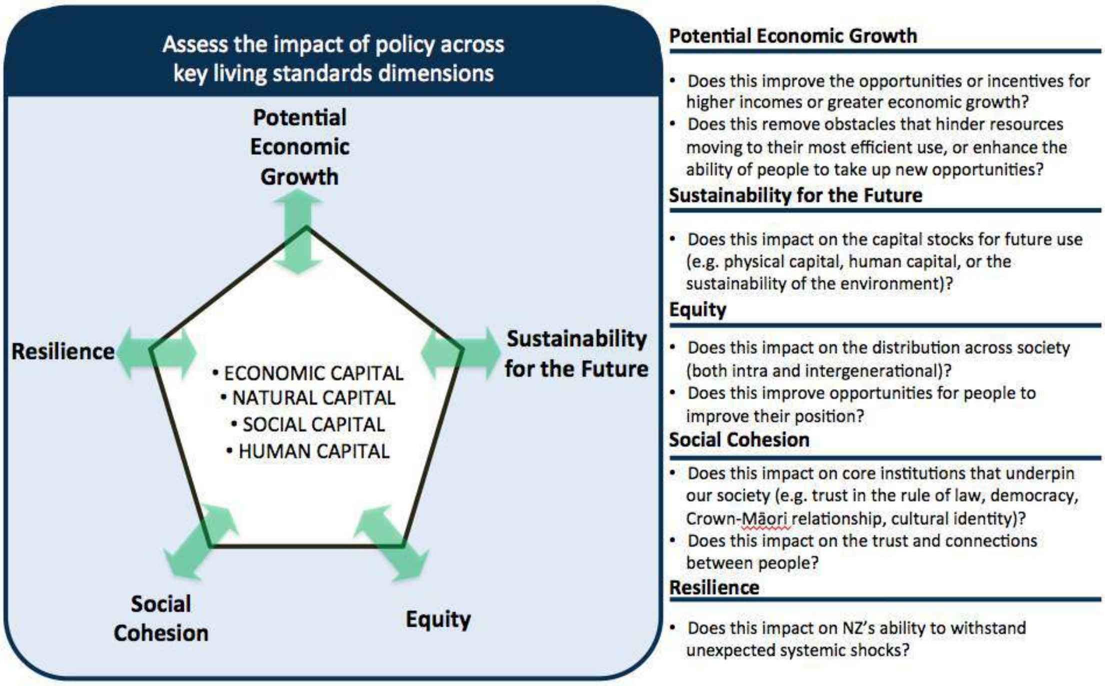


Figure 8: New Zealand Treasury Living Standards Framework (from Fairclough 2015)

The LSF is accompanied by the living standards tool, which is designed to assist policy analysts to incorporate the elements of the LSF. In Figure 8, the living standards tool is represented as a series of questions that can help analysts evaluate policy against the key living standards dimensions. The tool does not seek to assess or evaluate New Zealand's performance over time or against other countries, as the Treasury felt that this work was already being done through the Ministry of Social Development's Social Report,[4] the Sustainable Development Approach designed by Statistics New Zealand,[5] and the OECD's Better Life Index[6] (Karacaoglu 2012). The tool, while not yet formalised, can help begin a reflective process about whether policy and development trajectories are advancing New Zealand toward better living standards.

Going forward, the Treasury intends to increase the usability of the tool for the policy community and other interested parties. This includes:

- Developing "clearer definitions and how to assess the corners" (of the Framework diagram.
- Achieving "some (not necessarily total) agreement on valuable indicators,"
- Producing "case studies to demonstrate how to do it and the value add."
- "Establishing a network of policy advisors to support each other," (NZ Treasury 2015, p. 2).

Recently Treasury revised the LSF to explicitly incorporate resilience terminology. Although the framework shows it as one key element, there is significant overlap between social resilience to disasters and healthy economies, sustainability, equity, and social cohesion.

In their discussion of wellbeing economics, Dalziel and Saunders (2014) cite the LSF as a potential tool for pioneering transformation in how a nation can enhance the wellbeing of its people. It will be worth considering how the RNC-NSC research programme can compliment the LSF and perhaps work

[4] http://socialreport.msd.govt.nz - This report has not been updated since 2010.
[5] http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/Measuring-NZ-progress-sustainable-dev-%20approach.aspx - Reports related to this monitoring approach, do not appear to have been updated since 2011.
[6] http://www.oecdbetterlifeindex.org/countries/new-zealand/ - The OECD Better Life Index is designed to provide quantitative comparisons of wellbeing at the national level across a number of indicators. They also provide information at the sub-national level (in New Zealand comparing the North Island to the South Island). Data is provided mostly by the census and other Statsistics New Zealand sources. Data is updated annually, and available for download at: http://stats.oecd.org/Index.aspx?DataSetCode=BLI.

collaboratively to develop the LSF as a robust policy assessment tool for enhancing living standards, wellbeing, and disaster resilience.

National Resilience Framework

The National Civil Defence Emergency Management (CDEM) Strategy (2007) is the Crown's goals in relation to civil defence emergency management and their vision of a *Resilient New Zealand*. The vision contains a number of principles including:

1. Individual and community responsibility and self-reliance
2. A transparent and systematic approach to managing the risks from hazards
3. Comprehensive and integrated hazard risk management
4. Addressing the consequences of hazards
5. Making the best use of information, expertise, and structures

The goals guide CDEM agencies in their role in improving national resilience, focused mostly on risk and emergency management. This includes two objectives in relation to recovery: (1) "Implement effective recovery planning and activities in communities and across the social, economic, natural, and built environments" and (2) "Enhance the ability of agencies to manage the recovery process" (MCDEM 2007).

MCDEM has continued to develop their approach to resilience, as demonstrated by the conceptual National Resilience Framework developed by Horrocks (2014) (Figure 9). This includes the notable inclusion of references to "known and unknown threats" which reflects a move away from a narrow risk management perspective toward a holistic and integrated social-ecological approach to disaster resilience.

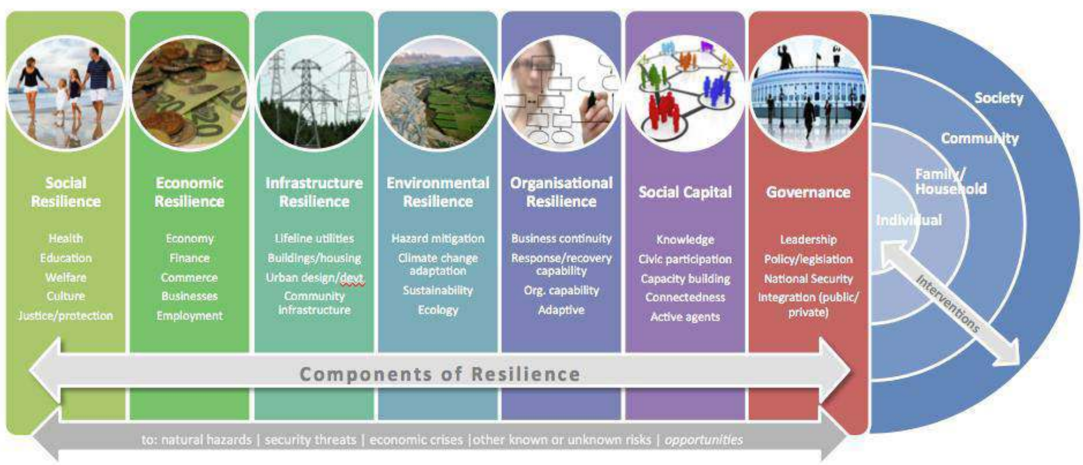


Figure 9: National Resilience Framework (Horrocks 2014)

The Resilience Framework currently only exists as a conceptual visualisation tool to emphasise that national resilience spans a broad range of activities and scales and to highlight the need for practical inter-agency and inter-sector collaboration (Horrocks 2014).

Moving forward, this framework (or some modified version) will be used to inform the development of the new National CDEM Strategy (due by end 2017, potentially reframed to be a *National Resilience Strategy*) that will likely include long-term targets, systems of assessment that guide where effort and investment should be directed and by whom, and monitoring and validation tools that assess whether policies and interventions are creating positive change on the ground.

As part of the Resilience to Nature's Challenges research programme, researchers will examine each of the resilience components identified in Figure 6. As with the Living Standards Framework it is worth considering points of alignment between RNC-NSC resilience assessment work and the emerging National CDEM Strategy. Establishing common terminology and collaborative processes will enhance the ability of the research to inform policy processes and for policy to utilise methods and actions identified through the research programme.

Sendai Framework for Disaster Risk Reduction 2015-2030

In April 2015, delegates from the 187 UN Member States adopted the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFA). New Zealand is one of the ratifying Member States, and over the next 15 years will be engaged with development, reporting, and implementing various aspects of the SFA.

In a reflection on the SFA and its implications for New Zealand, Berryman (2015) noted encouraging alignment between the SFA, recovery processes being implemented in Canterbury following the earthquakes in line with the ‘build-back-better’ ethos, and Christchurch and Wellington’s participation in the Rockefeller resilient cities programme.

The Science and Technology formula discussed as part of SFA development process at the 3rd UN World Conference on Disaster Risk Reduction, is potentially relevant for the RNC research programme. As seen in Box 1, the science and technology formula refers to the development of analytical and monitoring tools, which is a major component of the RNC research programme (IRDR 2015, p.2).

Box 1: Science and Technology 4 + 2 formula for implementing SFA

Assessment. Provide analytical tools to advance a comprehensive knowledge of hazards, risks, and underlying risk drivers > regular, independent, policy-relevant international assessment of available science on DRR, resilience and transformations.

Synthesis. Facilitate the uptake of scientific evidence in policy-making < synthesize relevant knowledge in a timely, accessible and policy-relevant manner.

Scientific advice. Translate knowledge into solutions > provide advisory capabilities integrating all S&T fields in collaboration with practitioners and policy-makers.

Monitoring and review. Support the development of science-based indicators, common methodologies and processes > harness / make use of data & information at different scales.

Communication and engagement. Closer partnerships between policy, science and society as well as between researchers > improve the communication of scientific knowledge to facilitate evidence-based decision-making (all levels of government; across society).

Capacity building. Promote risk literacy through curricular reform, professional training and life-long learning across all sectors of society.

5.5.3 Maturity Model Results

The maturity model (presented in Figure 2) helps evaluate the degree of fit that frameworks and resilience assessment tools have with a number of proposed optimal criteria. The criteria proposed in the maturity model presented in Figure 2, include: 1) highly developed definition of resilience, 2) iterative tool testing and refinement, 3) evidence of the tool’s efficacy through operationalization and informing policy, and 4) tests of validity.

The frameworks and tools presented in Section 5.5 were developed with a number of intentions and are at various stages of development. Therefore, the assessment of their maturity using our preliminary model is not intended to be a critique of the frameworks and tools. Rather, assessing their maturity levels (ML) provides some degree of guidance about the practicality of using these tools to realise our goals for resilience benchmarking, monitoring, and guiding policy and interventions.

The maturity levels assigned in Table 9 are based on preliminary reviews of each tool using available literature. There are five 'maturity levels' (ML) ranging from ML 1, which refers to *ad hoc* resilience assessment tools to ML 5, which refers to tools that are *Optimized and Adaptive*.

Due to the limited scope of this project, we have not conducted a thorough literature review and in-depth comparative analysis for each tool. Therefore the maturity levels should be treated as estimates.

The estimates in Table 9 indicate that Cutter et al.'s (2008, 2010) BRIC model, Paton and colleagues' Adaptive Capacity/Resilience Model, and the Canterbury Wellbeing Index have the highest maturity levels. These, along with the Community Resilience Index developed by Norris et al. (2008) and Sherrieb et al. (2010) and the City Disaster Resilience Scorecard, may provide useful early templates for developing multi-capital resilience assessment tools in New Zealand.

Interestingly, these tools emerge from different epistemological perspectives and employ different methodologies. The BRIC model and the Community Resilience Index are composite indicators that employ secondary data and focus largely on inherent community characteristics to provide a broad top-down assessment of relative disaster resilience across space and time. The Canterbury Wellbeing Index uses a combination of secondary and primary data to assess the wellbeing of a community across a number of dimensions, with direct pathways to policy and planning. The Adaptive Capacity/ Resilience Model uses primary data collected from surveys and information about specific hazards from various sources. The City Disaster Resilience Scorecard is an example of a 'bottom-up' tool designed to be applied and interpreted by the communities being assessed.

Composite indicators, like the BRIC model, provide relatively low cost, statistically validated assessments that can be applied across a large area and across time (depending on data availability). Empirical tools that require primary data collection, such as the Canterbury Wellbeing Index, Adaptive Capacity/ Resilience Model, and City Disaster Resilience Scorecard are more resource intensive and subject to inconsistent applications and interpretations by different users. They do, however, accommodate far more detail, nuance, and contextual information than composite indicators based solely on secondary data.

The Living Standards Framework, National Resilience Framework, and Sendai Framework for DRR are policy guidance tools, and therefore, did not rank as highly within this maturity model. They are, however, very relevant conceptual and decision support tools in the New Zealand environment. Frameworks such as these could be usefully developed and supplemented using versions of assessment tools such as a NZ BRIC Model, community or regional Resilience Index similar to the Canterbury Wellbeing Index, and community specific scorecards.

Finally, tools such as the AQDR, Framework for Measuring Transport System Resilience, the Build Back Better Framework, and City Resilience Framework are rapidly developing in various policy and practice contexts in New Zealand and internationally. These and similar tools should be considered by those wishing to develop resilience assessment tools and build upon existing work in engineered or other technical systems, and by those aiming to work in environments where these tools are already being employed. For example, the City Resilience Framework is currently being applied in Wellington and Christchurch through the Rockefeller 100 Resilient Cities programme.

Table 9: Maturity Levels of Selected Resilience Frameworks and Assessment Tools

	Definition Development	Tool Refinement	Policy & Operationalisation	Validity	Maturity level (Avg. Estimated)
Characteristics of a Disaster Resilient Community (Twigg 2009)	ML 5	ML 2	ML 3	ML 1	ML 2.75
Analytical Quantification of Disaster Resilience (AQDR)(Cimellaro et al. 2010)	ML 5	ML 2	ML 3	ML 1	ML 2.75
Baseline Resilience Indicators for Communities (Cutter et al. 2008, 2010)	ML 5	ML 5	ML 3	ML 5	ML 4.5
City Disaster Resilience Scorecard (UNISDR 2012)	ML 5	ML 5	ML 2	ML 1	ML 3.25
Community Resilience Index (Norris et al. 2008, Sherrieb et al. 2010)	ML 5	ML 5	ML 3	ML 1	ML 3.5
Framework for Measuring Transport System Resilience (Hughes & Healy 2014)	ML 5	ML 2	ML 2	ML 1	ML 2.5
Adaptive Capacity/ Resilience Model (Paton et al. 2015)	ML 5	ML 5	ML3	ML3	ML4
Canterbury Wellbeing Index[7]	ML 5	ML 5	ML 5	ML 3	ML 4.5
Build Back Better Framework	ML 5	ML 2	ML 3	ML 1	ML 2.75
City Resilience Framework (ARUP 2014a,b)	ML 5	ML 2	ML 2	ML 1	ML 2.5
The Living Standards Framework[8]	ML 5	ML 1	ML 2	ML 1	ML 2.25
National Resilience Framework	ML 5	ML 1	ML 2	ML 1	ML 2.25
Sendai Framework for DRR[9]	ML 5	ML 1	ML 1	ML 1	ML 2

[7] Evaluated for wellbeing rather than resilience
[8] Evaluated for the concept of higher living standards rather than resilience
[9] Evaluated for the concept disaster risk reduction rather than resilience

5.5.4 Assessment Conclusions

As noted by Cutter (2014): "Measurement tools cannot create a resilient community, but they can help show the path towards becoming safer, stronger, and more vibrant in the face of unanticipated events." Building resilience begins with understanding where we are, where we'd like to be, and through repeated trials and evaluation, building pathways to get there. There will not be a single best tool. We will need a suite of data collection and analysis tools including indicators and indexes that use secondary data, primary data collections tools such as survey to fill information gaps, and models and scenario tools to map paths forward

Robust assessment tools to benchmark resilience, monitor progress, and evaluate interventions will be an indispensible part of this journey. This will require a robust framework that can synthesize and provide context for these multi-modal assessments.

We will need to combine quantitative datasets with qualitative research to contextualise our approaches, and need to work directly with communities across New Zealand not only to gather information but also to tailor assessments and interventions to their needs (embodying the ethos of co-production at every stage of the research). The RNC-NSC should take a lead role in developing core assessment tools that can be applied relatively easily in a number of scenarios, locations, and at different levels of government. The research programme will also need to develop appropriate processes for developing bespoke tools to meet specific needs where applicable.

1.6 Recommended Resilience Assessment Approaches

1. **Start with a strong conceptual framework**
   Ideally, this framework will be co-created with stakeholders and populations who will influence and be influenced by resilience building interventions.
   Answer the questions:
   - What does resilience mean or 'look like' in this context?
   - For what reason are we building resilience?
   - For whom are we building resilience?

   For example, in a policy and practice context, it is practical to consider system resilience as a goal or development outcome and adaptation as one mechanism to move the system closer to that goal. An exclusive focus on adaptation occurs at the expense of understanding factors that enhance the capacity to absorb or cope with adverse events. Recognising the relevance of and conducting integrated evaluations of multiple system capacities helps develop policies and practices that both build and sustain resilience.

2. **Develop an operational resilience definition**.
   An operational definition is a clear, succinct definition of a measure. This definition is different from general definitions of resilience, such as the meta-definition proposed in this report. It specifies the observable elements of the resilience construct that an assessment will measure.

3. **Identify the drivers of resilience for your system of interest and the observable features that can be used as indicators for those drivers.**
   For example, the developers of the BRIC resilience assessment tool combined the notion of distinct capitals and inherent system characteristics identified in the Disaster Resilience of Place model. A set of indicators was chosen to represent each of the six capitals (or types of resilience) and drivers of inherent resilience, based on empirical, conceptual, and theoretical justifications (Cutter et al. 2014).

4. **Clearly specify the goals or desired outcomes of the assessment.**
   Some assessments are purely to advance knowledge without a specific agenda for change or to provide a baseline or benchmark of resilience. Other resilience assessments are important communication tools. The act of assessment may also facilitate engagement and catalyse resilience-building interventions or guide strategic investment decisions. Different goals

require slightly different set of tools: composite indicators; scorecards, checklists, and surveys; maps; computational models; and programme assessment tools.

5. **Develop the assessment tool or suite of tools that will allow you to move toward that goal.** Tools that require a high level of expertise to implement and interpret are useful for certain goals such as guiding construction planning and resourcing decisions (e.g. Cimellaro et al.'s 2010 Analytical Quantification of Disaster Resilience Model). However, these tools are often ineffective for communicating to non-expert audiences, and cannot be easily distributed for implementation by different communities.
   The way the data is collected, processed, and communicated should be driven by the intended outcomes, not the other way around.

   As observed by Hughes & Healy (2014) in their development of a resilience assessment tool for the New Zealand Transport Agency,

   > "Quantitative approaches tend to be less flexible, time consuming and appropriate for more narrow assessments of networks and systems. They are data intensive and can be difficult to implement. Qualitative assessments are, by nature, more subject to interpretation, but are flexible in terms of scale and context, and can provide wider process and organisational benefits due to the necessary involvement of operators and managers," (p. 36-37).

   Ultimately the authors opted for a broadly qualitative framework underpinned by assessment indicators that could be recorded as quantitative data.

6. Test, revise, share, revise, validate, revise
   Resilience assessment tools need to be, "test, verified, and made simple," (Cutter 2015) to be effective. Any resilience assessment requires 'living tools' to capture and reflect the dynamic and complex nature of 'living environments' and needs to go through several iterations, tests, validation assessments, and revisions. While having consistent measures over time is important, creating space for tools to adapt to the needs of the users helps avoid static and disconnected assessments. Once the tools are tested and ready to be implemented they can be shared with end-users. The users can provide valuable information for further tool refinement.

Finally, those developing resilience assessment tools need to consider how they may integrate with other models or measures with which they may need to interact, and how the assessment tools may 'behave' in different contexts. For example, efforts to build resilience in a system will be enhanced by awareness of the hazards and risks to which the system is exposed (while accepting that accurately predicting every hazard and its associated risk is implausible). Context is critical for effective tool development. Modellers may choose variables based on research conducted in very different environment without a true understanding of the context of the place being measured. Even the application of specific variables could change by hazard context (Burton 2015). Therefore, tools developed in other context will need to be carefully 'translated' using local insight and information.

6 Where to from here?

This short-term project will create a foundation for the launch of the RNC-NSC in July 2015. The outcomes will feed directly into the work of Toolbox 7: Resilience Trajectories. The Resilience Trajectories toolbox will be a resource and connection point for all of the other toolboxes and priority research areas. It will also be imperative to align the work of the Resilience Trajectories Toolbox with priority policy areas in New Zealand. In particular we need to consider how to develop resilience assessments and monitoring which may be able to intersect with the National Resilience Strategy (2017), the ongoing development of the Living Standards Framework, and reporting requirements related to the Sendai Framework.

In Deliverable 2 and the Multi-Capital Resilience Indicators database, we begin to discuss the relative value and efficacy of different types of indicators. As this work progresses, we will need to consider specifically, how we develop more "leading" indicators. Leading as opposed to "lagging" indicators provide a better picture of where we are going, rather than where we have been or where we are currently. Projecting future trends and incorporating models of potential changes (gradual or acute) is the next big challenge for resilience assessment. These considerations will be explored further through ongoing development of the Resilience Heuristic (introduced in Deliverable 3).

This report provides the foundation for an on-going conversation about New Zealand's pathways toward a more resilient future. The short-term Resilience Benchmarking and Monitoring review endeavoured to address major debates in the disaster resilience space, create a common language within the RNC-NSC, evaluate existing resilience benchmarking and monitoring tools and indicators, and provide some early guidance for those embarking on resilience assessment design in the coming years. The review is by no means comprehensive, but a broad survey of the resilience assessment landscape that can provide an accessible platform from which to launch future research. There is an additional companion piece currently under development providing more detail on resilience research and initiatives that are underway in New Zealand. This should be available in August 2015.

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