Australian climate extremes and building transport network resilience

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Executive summary: This case investigates the role of the Queensland Reconstruction Authority (QRA) in improving resilience of the road network in Queensland, Australia, following floods in 2010-11. Over ten years the QRA's remit expanded from oversight of asset repair to include longer-term hazard exposure concerns and community-oriented initiatives. Capabilities (developed in response to a crisis) have been maintained through the QRA transitioning from a temporary to a permanent entity.

Tags: Tropical Cyclone Yasi, transport, road network, regional crisis, local community, resilience theory, flood risk, technical and adaptive change, Cynefin framework, capacity-building

Section 1. Background and introduction

Infrastructure system resilience requires not just engineering design expertise, but also an understanding of exposure to hazards, how that exposure is changing, and how the rules governing decisions determine certain outcomes. This case study focuses on the implications of this for transport infrastructure, with a primary focus on roads. It covers a series of major flood events and their impact on the evolution of disaster risk governance and the resilience of road infrastructure in Queensland, Australia.

The case presents the need to adopt a systems approach to safety in addition to more traditional engineering concepts of safety. Traditional road transport safety focuses on how asset design and management minimise accident frequency/severity on the road itself. While systems thinking has been incorporated into transport safety in recent decades, this case takes the concept further. It adopts a socio-technical systems perspective that considers the criticality of the service provided: community survivability and resilience is fundamentally linked to the availability and functioning of transport connections.

Australia often hits global news headlines with climate extremes – droughts, fires and floods. Extended drought in the early 2000s led to major investment in water treatment and recycling systems. This period was immediately followed by major flooding in 2010-11. The extent of damage caused by this flooding resulted in the establishment of the Queensland Reconstruction Authority (QRA) to fill a major capacity gap in the management of a state-wide reconstruction process. The establishment and evolution of the role of the QRA provides a case for exploring the evolution and advancement of disaster risk governance and the implications for how critical transport assets are managed. A more detailed description of what happened in Queensland and the approach to creating this case study is available in the longer version of this research, which presents more detailed evidence.

"We can't stop these floods. The scale of them is beyond the resources of government to deal with. So, we are a flood city. We're a River City. We'll forever remain that way. So, let's accept that and not pretend that someone is coming in on their white shiny horse [to] build … some kind of hard engineering solution here that's going to fix the problem. And working that through with the community to get that acceptance, [we can] then talk about: 'Well, what can we do to adapt or to reduce the consequence?' which was sort of the start of our journey on resilience." (Case study interviewee)

Context

Queensland, Australia, has a population of approximately five million people (Australian Bureau of Statistics, 2020a) and an area of 1.7 million km², more than seven times the size of the United Kingdom. Of the total population of Queensland, 64% lives in the (mainly coastal) cities and the rest in rural areas (Australian Bureau of Statistics, 2020b). The state has over 183,000 km of roads (Department of Transport and Main Roads, n.d.) of which 18% is managed by the state's Department for Transport and Main Roads (DTMR) (Queensland Government, n.d.) (see **Figure 1**).

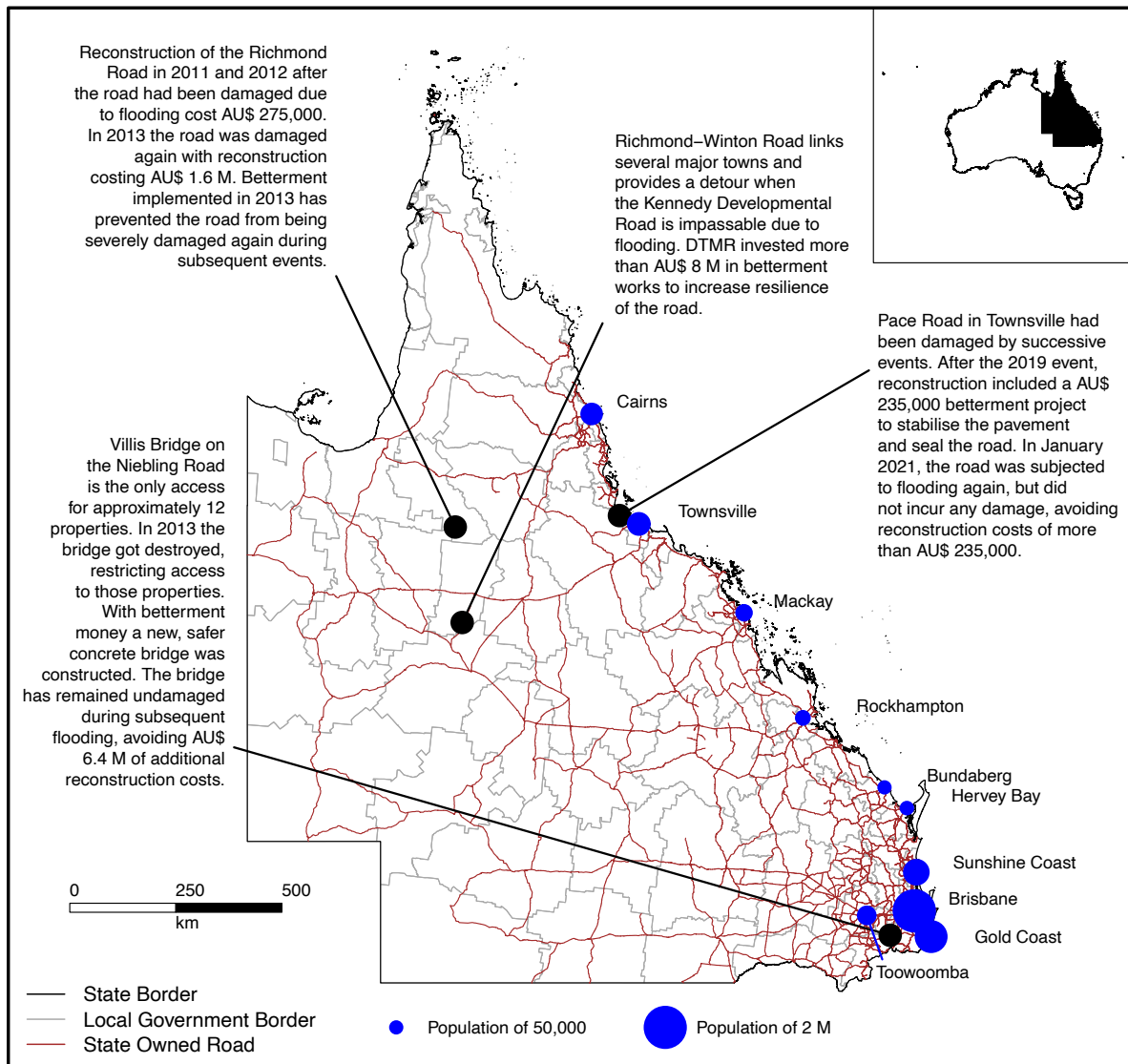Royal Academy of Engineering

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Figure 1. State owned road network of Queensland, Australia. Red lines represent state owned roads. Grey lines represent local government borders. The 10 biggest cities/towns in Queensland are shown (with a population of 50 thousand or higher). Annotations provide select examples of recovery interventions that include build back better (betterment) of the transport infrastructure system. For reference: AU$ 1 is approximately £ 0.54. Sources: State of Queensland (Department of Resources), 2021a (state road network); Australian Bureau of Statistics, 2011 (country borders); State of Queensland (Department of Resources), 2021b (state borders); State of Queensland (Department of Resources), 2021c (local government borders); Queensland Reconstruction Authority, n.d. (betterment case studies).

The climate in Queensland varies from tropical to very dry and the state has a long record of droughts and floods. After a long period of drought, flood events in 2010/11 resulted in unprecedented damage estimated at AU$ 15.7 billion (approximately £8 billion) across the entire state (World Bank and Queensland Reconstruction Authority, 2011). In response to this event the QRA was established as a temporary organisation to oversee the reconstruction process. The QRA was given the mandate to distribute funds made available by the national and state government. The QRA's task was to deliver this funding to local councils who had assets in need of repair or reconstruction and to provide coordination and efficiency that could not be achieved by the councils managing their individual programmes alone.

Over the past decade, the way in which the QRA undertakes its role has evolved. It started out by managing reconstruction projects, focusing on repair and returning the road network to a condition that resembled pre-disaster function. This was predominately driven by the rules surrounding the allocation of federal funding. The QRA's remit was then expanded to allow greater scope for increasing robustness through the introduction of a build back better fund. More

recently, the remit was expanded even further following the QRA's establishment as a permanent entity. It has since become more involved in community resilience-building initiatives. **Figure 2** provides an overview of the events and changes that have occurred, as well as the development in knowledge that were necessary to facilitate these changes (explained further in the next section). The development of activity can be characterised through changes in the system boundaries of QRA's remit, reflected in the 'system intervention' in **Figure 2**.

We adopt a version of Snowden and Boone's (2007) Cynefin framework to explain the nature of this changing remit[1]. Initially the system of intervention for QRA consisted mainly of the road network assets. Following an initial period of 'chaos' in establishing the organisation during a response phase, we suggest that the organisation settled into something that could be classified as a 'complicated' operating basis. Expert engineering knowledge was necessary to

develop solutions for reconstruction and the solutions were mainly technical interventions (for example reinstating road pavements).

Over ten years the QRA's system of intervention has expanded to include wider considerations for the environment (such as the future threat of natural hazards) and communities. This goes beyond the initial mandate of recovery programme coordination and involves a more 'complex' operational context. This requires different types of knowledge and there are not always obvious engineered solutions to problems. These developments were the result of repeated experience of flooding and the associated learning and capacity building that resulted from that. The repeated experience also provided the political will to look for more holistic approaches towards the management of flood risk (**Figure 3**).

Section 2: Analysis and insights

In this section we examine three key themes in the evolution of

resilience management of transport infrastructure in Queensland and the role of the QRA. While these themes can be considered separately, they are closely linked, and their combination has been important for Queensland's path to improving its disaster resilience. Key learnings from this case can be drawn through these themes.

The Queensland Reconstruction Authority as a resilience broker

The formation of the QRA led to a process of transition in managing checks and balances of disaster recovery at a local, state and national level. The QRA had to engage local governments to help them in that transition and, at the same time, had to show the Australian Government that they knew what they were doing. From the start the QRA worked to build relationships and trust with the local, regional and national levels of government. These relationships allowed them to act as a broker for building resilience in two directions. From the top down, they receive lump sum funding from the national
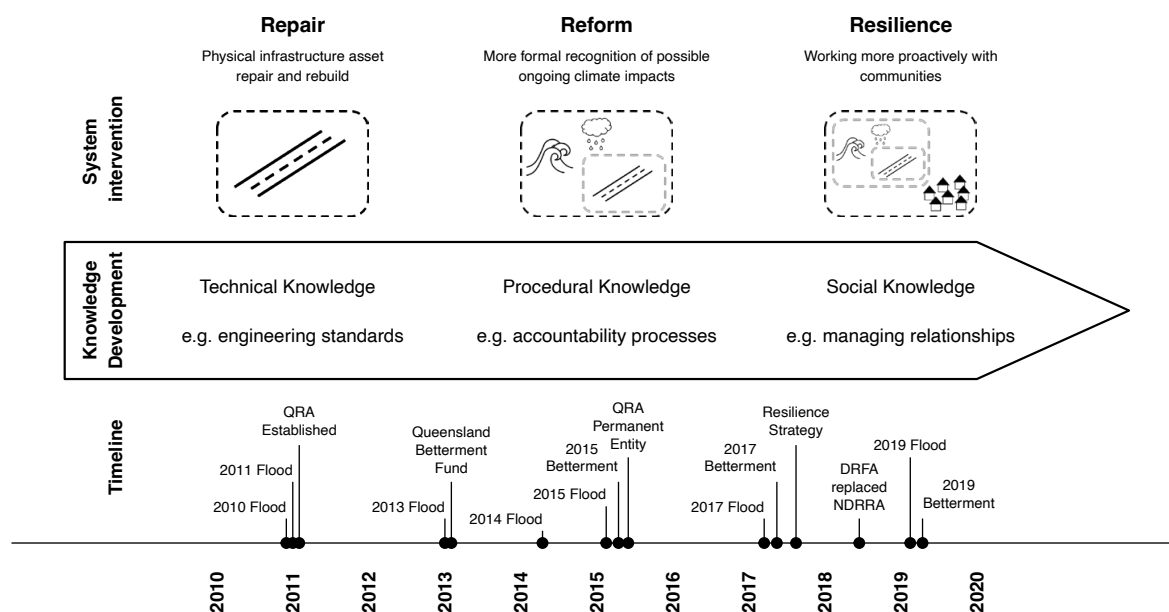

Figure 2. Timeline of events in Queensland that led to changes in QRA's responsibilities. The figure shows the changes in the system encompassed by the QRA's remit, as well as the development of knowledge over the past decade. The timeline shows the most important events and only includes the most severe flood events. DRFA = Disaster Recovery Funding Arrangements, which replaced the NDRRA: Natural Disaster Relief and Recovery Arrangements.

Complex

Characteristics: flux and unpredictability; no right answers; unknown unknowns; many competing ideas; need for creative approaches; pattern-based leadership

Example: retrofitting a road network for emerging future technologies and climate change.

Resilience lens: decisions involving community liaison (i.e. not just an expert making a decision), e.g. land use change, managed retreat from a floodplain.

Complicated

Characteristics: expert diagnosis required; cause-and-effect relationships not apparent; more than one right answer; known unknowns; fact-based management.

Example: designing a structural system; selecting an asphalt mixture.

Resilience lens: changing features of the system design to manage risk, e.g. applying rock protection to prevent scour, use of alternative technology.

Disorder

Chaos

Characteristics: high turbulence no clear cause-and-effect relationships; unknowables; many decisions to make and no time to think; high tension; pattern-based leadership.

Example: providing infrastructure services right after a disaster.

Resilience lens: acting according to a pre-prepared response plan, using relationships, experience and knowledge to adapt to the situation

Simple (or obvious)

Characteristics: repeating patterns and consistent events; clear cause-and-effect relationships evident to everyone; right answers exist; known knowns; fact-based management

Example: selecting width for a two-lane road.

Resilience lens: design interventions according to standards, e.g. increasing the size of a pipe based on design criteria for capacity.
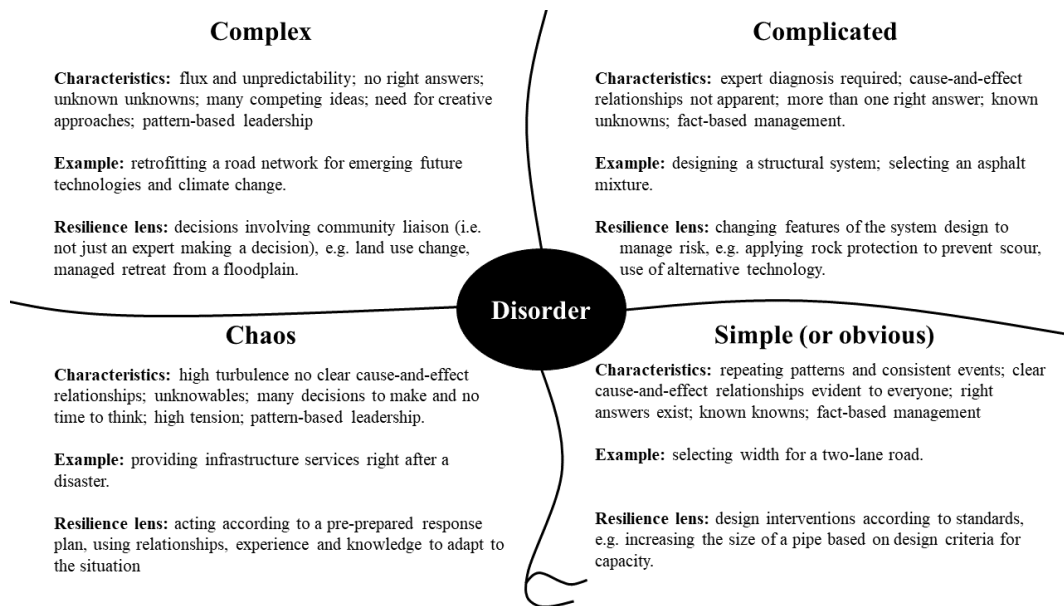
Figure 3. The Cynefin framework applied to road infrastructure decisions. Each domain has different characteristics and requires a different approach to management. Also, the approach to managing resilience varies depending on the domain. Adapted from Snowden and Boone (2007) and Chester et al (2019) and a hierarchy of resilience measures presented by MacAskill & Guthrie (2015).

and state government, who place trust in the QRA to distribute that funding to local governments in an efficient and effective manner. From the bottom up, the local councils appeal to the QRA for changes in policies and funding arrangements. They share their needs with the QRA and the QRA can advocate for change at a regional and national level. One example is the Betterment Fund, which was called for by local governments, advocated for by the QRA and eventually funded by the Australian and Queensland Governments.

The ability of the QRA to act as a resilience broker can be summarised by some key characteristics of the QRA as an organisation:

1. It has a mix of permanent employees and temporary employees from government departments and contractors. It draws on knowledge from both the public and private sectors and distributes that knowledge to local governments, when and where needed. It can scale its operation up and down to meet demand.

2. It facilitates resilience-building by bringing people together. Local forums have expanded into regional strategy development activity.

3. It has the financial capacity to take on risks for initiatives where there are potential wider benefits to be gained through shared learning. Together with local councils, the QRA facilitates the implementation of new plans and new solutions. This has been aided by the support of the state and national government.

4. The QRA has demonstrated the ability to operate within the legal bounds and evidence-base requirements. At the same time, it has built relationships with the local councils, allowing them to implement new projects and ideas with their cooperation.

The relationships are not always smooth. While local government representatives express appreciation for their relationship with QRA, there is also some discontent. This is associated with (A) the added burden of processes developed for claiming compensation and (B) local

coordination does not extend to the established local presence of the QRA in more remote regions.

Funding Arrangements

Recovering from a severe flood event may require redistribution of money across different levels of government as the costs can be well beyond a local government's financial capacity to manage. This is where special recovery financial mechanisms come into play, often involving national government subsidy of local costs. There are several ways in which the availability of funding and the arrangements surrounding the distribution of funding can hinder or facilitate resilience building. Queensland's experience provides some examples:

1. The main recovery funding provision in Queensland did not, until recently, provide for betterment. A separate line of funding for betterment existed but was practically inaccessible. This limited the options for improving the robustness of assets when the QRA set out to manage reconstruction after the

2010/11 floods. However, building on the experiences of managing repeated flooding, it was able to negotiate a new funding mechanism. From 2013 onwards the Queensland Betterment Fund allowed for 'building back better' by increasing the robustness of infrastructure assets with respect to flooding (See **Figure 1** and **Figure 4** for examples). In addition, the new Disaster Recovery Funding Arrangements (DRFA) introduced in 2018 provide an opportunity for reconstruction programme savings to be spent on other preparedness and resilience-building initiatives.

2. Allowing local councils to implement the reconstruction work can result in efficiencies and, under the new DFRA, can help save money that can be used for resilience building. Put in other words: paying the local government to do the work is resulting in savings that can be spent on other projects.

3. A related financial factor is the capacity of local councils to invest early to mitigate flood risk. It is generally accepted as impractical to engineer a solution to fully prevent flood damage and achieve an absolute level of safety. Instead, there is an acceptance of the need for communities to cope with some level of flooding. The local councils recognise the need for improving community resilience and the funding made available for these purposes (via the QRA's wider resilience agenda) has been used for a variety of information campaigns.

This case shows that, in the short term, revising funding arrangements can help remove barriers to resilience building. This has been implemented with the aid of the QRA. However, limitations remain and there is ongoing debate over finding a balance in investing across mitigation, preparedness and recovery. The benefits of resilience building are not easily captured in standard cost-benefit analysis processes.

Explicit and tacit knowledge

One of the key capabilities that the QRA has developed over the past decade is knowledge acquisition. Here we make a distinction between two types of knowledge the QRA has gathered and developed: explicit knowledge (design standards and evidence of flood damage) and tacit knowledge (managing social relationships).

The QRA has accumulated extensive knowledge on the state of the road transport network. It set up a database containing damage and repair data that has been gathered through local councils and the DTMR. This has helped resilience building in Queensland in several ways. It provides evidence for funding claims, enabling more transparent claims management. It also provides the QRA with the evidence to make a case for changes in funding arrangements, such as in the case of the Queensland Betterment Fund. Finally, the database allows for a more comprehensive analysis of the state of the transport network than existed before. This can assist in finding vulnerable points in the network.

Tacit knowledge also developed over time. When established in 2011, the QRA focused on repairing assets. It was responsible for overseeing the distribution of funding and, as a result, developed knowledge on how to effectively manage a state-wide programme (for example it developed and implemented processes for funding applications and approvals, including the development of online platforms). The QRA also developed new networks and became knowledgeable in managing the relationships with local councils, state agencies and the federal government. When its remit expanded to include community resilience, its experiential knowledge expanded to creating awareness raising campaigns and increasing community preparedness. Thus, throughout

Figure 4: Aurukun Access Road (the only road link to and from the Aurukun community). Left: Gravel road that was damaged in 2010, 2011, 2012 and 2013. Right: Bitumen seal instated in 2013 along a 10 km vulnerable section. This has since withstood the impacts of eight natural hazard events (photos courtesy of QRA).

the past decade the QRA acquired knowledge with very different characteristics: from technical, to financial management, to social and cultural.

Section 3: Discussion and transferable learnings

This case study calls for management approaches that go beyond a mindset that focuses on infrastructure as a complicated system to an approach that engages more holistically with the complexity associated with the infrastructure system as a service. While the context for this case study is specific, there are some observations that may be generalisable to other organisations seeking to improve societal resilience.

There are two distinct types of change within this case study: technical and adaptive (Heifetz & Linsky 2002). The QRA began its work facilitating technical changes, such as improving the engineering standards and advocating to change eligibility requirements for rebuilding roads and bridges. Repeated flooding resulted in repeated damage, helping to create the business case for going beyond restoration to a former state (through repairs and treating the problem as 'complicated'). To build resilience in the system, the QRA had to take an adaptive approach to leadership – redefining and expanding its interventions in a way that is reflective of managing complex problems. The QRA began this work as a perceived natural extension of its activity, although there was no formal mandate to do so.

This process of adaptive change had several distinctive features. First, there has been a multi-year process of engagement with local communities. This has allowed the QRA to build social connections across the system so that it can understand local needs and help build local capacity. Although there

is some centralised expertise in the system, there is an important role for the local communities themselves to develop responses to flooding in their area. Second, the development of a database of damage and repair information means that people from across the system have a shared way of seeing the network, despite there being hundreds of miles of distance between stakeholders. This combination of activities means that the QRA has made the network socially denser—in effect, more complex—but at the same time has made it easier to understand its characteristics.

This added social complexity may seem counter intuitive. Often, added complexity in an organisation is seen as more difficult to manage and more costly. Very often, we approach problems by simplifying them first – and yet that was clearly not the approach to change here. In this case, the complexity was helpful because it created value in parts of the system: for example, the closer relationships between the QRA and the communities enabled initially a more effective and timely allocation of funds and, later, an ability to build capacity at local level. The relationship between the QRA and the Australian Government allowed the system to allocate funds in line with policy and with clear accountabilities. The QRA thus created a key mediating role, in a way creating more complexity in the network, but also adding the necessary capability to achieve wider success in disaster risk management.

While QRA was introduced as a new entity, it essentially slotted within the existing hierarchical governance system. The national and state governments decided to make money available and exercised their power to give the QRA the mandate to distribute that money. The QRA's power to approve funding for local projects is bound by the

legislation and guidelines set within this system.

In conclusion, the way in which the QRA worked to build resilience to flooding in Queensland's Road network was characterised by:

1. Creating a knowledge base to ensure that 'technical' problems could be resolved to an appropriate standard, more consistently.

2. Adding density to the social fabric of the system as a way to 'shorten the distance' between national and state government and local communities and to provide a way to transmit knowledge between groups. The QRA achieved this by building its network with the local communities early in the process and in parallel with technical problem-solving.

3. Expanding its remit beyond an asset reconstruction programme to engaging in capacity-building, despite the added complexity this brings to defining what success looks like for its own operations

4. Managing the tensions that arise from differing interests and priorities across the system.

To do this, leaders need to be able to understand multiple points of view, to pay close attention to stakeholders and to be more invested in solving problems than in 'being right'. These capabilities are relevant in a broad range of situations where the safety of a complex system involves behavioural as well as technical components.

List of acronyms

DTMR Department of Transport and Main Roads

DRFA Disaster Recovery Funding Arrangements

NDRRA Natural Disaster Relief and Recovery Arrangements

QRA Queensland Reconstruction Authority

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Endnotes

1. The Cynefin framework is a descriptive rather than a diagnostic framework, helpful in this case for describing the evolution of decision-making in Queensland over time.

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