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Enhancing the Resilience of Civil Infrastructure to Natural Disasters – A Stakeholder Informed Approach

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***Abstract*:** *A number of geographic areas of Australia are subject to frequent and significant natural disasters that are, typically, the result of major weather events such as cyclones or flooding. Such events impact individuals and businesses both directly and indirectly through the disruption of the routine movement of goods, services and people. This paper presents findings from a project to investigate two case studies of cities in Australia facing ongoing risks from natural disasters and which applied resilience thinking using a stakeholder-based bottom up approach. Workshops held in each city identified tangible potential interventions to improve the disaster reliance of the communities and the infrastructure including new approaches using disaster readiness plans, new sensor technology approaches and local renewable power, repurposing facilities and infrastructure for disasters, strategic tactical planning for evacuation, relief and rebuilding, and policy actions to streamline governance, create social capital around resilience, and co-ordinate agency responsibilities.*

Keywords: Climate Change, Disaster Resilience, Stakeholder Engagement, Stakeholder Informed Interventions

1. Introduction

1.1. Future Trends affecting Transport Related Civil Infrastructure

In the coming decades the design, construction, and maintenance of civil infrastructure will face a range of emerging challenges that reflect a growing number of interconnected environmental, social, and economic pressures or trends. For instance, environmental pressures will include the impacts of climate change affecting natural disasters, rainfall patterns, and temperature profiles; economic pressure will include materials and resources shortages, increased maintenance costs, and predicted increases in energy and resource prices globally; and social trends will include a shift to lighter vehicles, reduced use of cars due to higher fuel costs, and political pressure to respond to climate change and population growth. Responding to such pressures will be a complex task and will see a focus on the maintenance and enhancement of the resilience of new and existing infrastructure including that supporting logistic and transport operations.

Of particular consequence to such infrastructure is the international trend of increased climate related disasters as shown in Figure 1. According to the Council of Australian Governments in 2011, '*Australia has recently experienced a number of large scale and devastating natural disasters, including catastrophic bushfires, far reaching floods, and damaging storms. Natural disasters are a feature of the Australian climate and landscape and this threat will continue, not least because climate change is making weather patterns less predictable and more extreme. Such events can have personal, social, economic and environmental impacts that take many years to dissipate*'.[1]

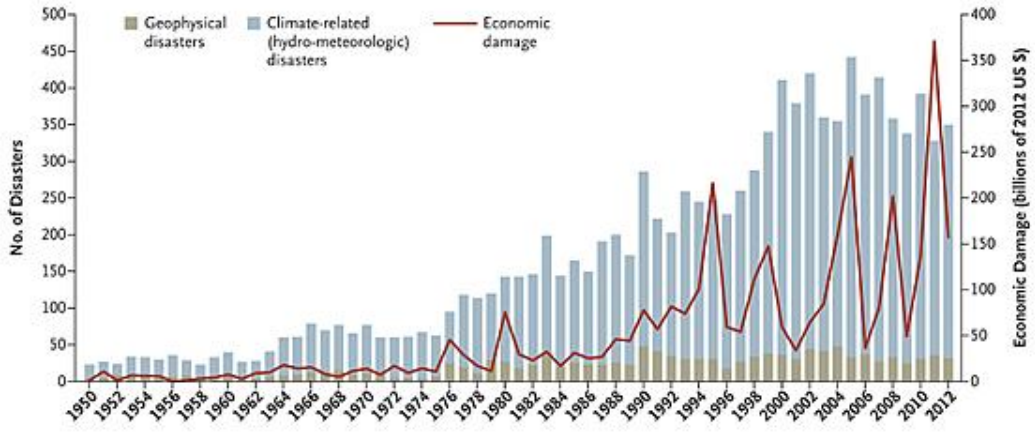

Fig 1: Estimated number of and damage caused by reported natural disasters 1950-2012[2]

Hence as the world comes to grips with the need to respond to human induced climate change, a clear focus for research is that of understanding how to increase the resilience of civil infrastructure to natural disasters in an efficient and effective way

Figure 2: Flood damaged roads in Central West Region, Queensland, Australia in early 2011[3]

Not only does climate change affect the severity and frequency of natural disasters, it also has a number of additional impacts on civil infrastructure, as shown in Table 1 for the case of road and transport infrastructure.[4]

TABLE 1: Impacts of Climate Change on Road and Transport Infrastructure[4]

Issue	Implications for Roads
Temperature increase & severe droughts	Increased maintenance of surface cracking in roads due to changing landscape topography caused by evaporation. Maintenance caused by increased wear and tear of road surfaces due to temperature increasing the fragility of the road surface. Increased rehabilitation of road surfaces due to surface cracking, warping and asphalt bleeding (flushing).
Increased extreme rainfall events & flooding	Increased amount of road maintenance caused by potholes created when water enters the road surface. Increased road rehabilitation due to flooding events affecting large expanses of roadways. Decreased ability for maintenance and rehabilitation to take place due to extreme weather events affecting construction days and access. Road flooding putting pressure on road network and drainage systems.
Sea Level Rise	Salt water corrosion of roads due to flooding increasing the water table and to sea level rise. Increased storm surge and wave impact on coastal and low-lying coastal areas.
Increased Cyclones	Increased debris on roads causing road damage and traffic hazards.

These are summarised by the Council of Australian Governments (COAG) National Strategy for Disaster Resilience, '*Following a disaster, recovery efforts may require significant infrastructure reconstruction. Building public and private infrastructure to a more resilient standard, if appropriate, taking into account cost-benefit and other considerations, will reduce the need for significant expenditure on recovery in the future*'.[1]

The approach adopted to help create a more resilient future in these remote areas used the kind of 'resilience thinking' suggested by Walker and Salt in 2006[5] and elaborated for settlements by Newman, Beatley, and Boyer in 2009[6]. It used a stakeholder-led approach on the basis that local knowledge was the best way to create local responses to the growing need for long term disaster-related resilience planning.

2. Findings of Stakeholder Consultation

2.1. Vision for Disaster Resilient Cities and Infrastructure

Externally facilitated stakeholder workshops were conducted in two Australian cities experiencing natural disasters, namely Townsville, Queensland, and in Broome, Western Australia in late 2014/early 2015. Each involved some 30-35 stakeholders engaged in disaster response and recovery, including representatives of the emergency services, government agencies, community groups, infrastructure providers, media, and local businesses. Despite having many overlapping interests these different groups rarely come together to engage in planning for disaster resilience, hence the workshops were structured to integrate information and enable new ways of creating the future.

The process is based on 'Collective Social Learning', created by Professor Val Brown[7], in which the facilitator takes participants organised into small groups through four stages. In the first stage the participants are invited to ignore constraints and dream about 'what should be' in the case of, for example, a cyclone response. Then once this unbridled vision is created the teams consider in stage 2 the 'what is' and look for both things that are currently enabling that vision (which tells us what is working well), as well as things that are hindering achieving that vision (which tells us what can be worked on). The third stage is a creative process where the teams consider 'what could be' and list actions that can be taken to either further strengthen an enabler identified in the previous round, or actions that can be taken to deal with disablers. This is the really valuable part for governments at State and local level as it will provide them with guidance straight from those involved as to where they believe actions can and should be taken. The final stage is a personal one where each participant considers an action that they can take in the 'what can be' capstone round. This lasts stage is particularly important and empowering, not least as it brings the conversations of the day down to a personal level and helps the participants gain ownership of the whole process

Using this process, the following question was used by the expert facilitator. Miss Candia Bruce, as the provocation for the two workshops outlined above: [8]

> *"How can we learn from your experiences of past disasters to ensure our cities are resilient to future shocks or stresses; in particular in relation to transport and logistics networks into the city prior, during, and after a disaster?"*

Participants were then invited to create a vision for the future related to resilience to natural disasters and the following provides a summary of the combined findings from both workshops. As can be seen there is a strong focus on transport networks and related infrastructure, along with an equally important focus on whole-of-community preparedness which also contains elements related to transport networks. The following represents a summary of that vision: [8]

> *The transport network is sufficiently resilient to ensure continuous or quickly restored routes after a natural disaster, such as a cyclone or flooding, drawing on roads, rail, shipping, and airport facilities… In the case that the transport network is interrupted there would be clarity around the critical and/or alternative paths that would be the priority for recovery efforts… Such prioritisation would be informed by real time data to identify the location of interruptions to the transport network (such as tilt sensors on electricity poles or trees and reconnaissance drones)….*
>
> *The resilience of the city infrastructure would be sufficient to provide uninterrupted, or quickly restored, power supplies that draw on locally generated clean energy… and buildings and facilities would have high cyclone resilience with particular facilities identified as playing a role in the recovery process.*

The response to a natural disaster would be swift, well informed, and understood by the community so that we are "not caught out"... The evacuation routes would be well known and it would be clear which facilities and buildings are being used for coordination and recovery purposes with appropriate resources provided for them (including in isolated communities)… The roles and responsibilities of various players would be clear and the appropriate skills and training would be provided to response agencies, businesses, and the community to ensure high levels of coordination and an efficient and effective response…

Residents would have a high level of preparedness and understanding that would reduce the impact of the disaster and allow them to contribute to the recovery as a whole-of-community effort that harnesses and strengthens existing relationships and mobilises community resources… Business continuity would be supported along with harnessing business knowhow and resources to support resilience building and recovery efforts… The process to support recovery would be streamlined, avoid red tape, and provide quick access to funds that can be used to build long term resilience.

2.2. Stakeholder Preference for Intervention Projects

Following a process to consider what currently exists that either would enable or disable the achievement of such a vision the participants focused on identifying actions that could be taken in order to increase resilience to natural disasters both directly and indirectly related to transport networks. The following provides a summary of the key activity streams identified by the participants that are intended to be the basis for pilot trials in the second stage of this project. [8]

Activity streams related specifically to civil infrastructure:

- New Disaster Readiness Plans: The assessment of the natural disaster readiness of infrastructure: A key part of mitigating the damage from natural disasters is to identify infrastructure and facilities that have low or diminished readiness for disasters. This project would focus on developing and implementing a stakeholder engagement process to investigate the 'Disaster Readiness' of roads and transport infrastructure (with the potential to expand this scope to include buildings, service infrastructure, and other key assets). Once identified the process would consider costs and benefits associated with remedial actions with a priority on assessing infrastructure and assets critical to the short term recovery effort. The potential economic and social impacts of such critical infrastructure failing will be considered. The outcome of the project would be to recommend specific infrastructure and/or assets to be considered for remedial action, the development of response metrics and post event damage assessment tools, and recommendations related to the potential to upgrade design codes and performance standards.
- New Sensor Technology: The use of sensor data to inform a rapid response to transport network interruption: Rather than manually surveying the extent of damage to the transport network following a cyclone or flooding event - which may take, at minimum, several hours – this project would investigate the potential to significantly shorten this process by accessing data collected during and shortly after the event. Data would be collected using sensors (such as tilt sensors on electricity poles, light poles, and large trees that are located near critical transport nodes), and through the use of reconnaissance drones or fixed cameras to photograph key transport network nodes. It is proposed that this data could be analysed during the disaster event to identify interruptions to critical-route intersections and/or transport routes that would be prioritised for emergency response vehicles. Further the data could also be used to route general emergency vehicles around obstacles shortly after disaster events.
- New Local Renewable Power: The nexus of transport and energy for isolated communities: It is often the case that isolated communities source energy from diesel generators providing electricity to a local grid. The provision of the diesel is reliant on the resilience of the transport network to disaster events. A focus on local energy generation (through renewable energy) stands to both strengthen the energy resilience of isolated communities, and also reduce the regular transportation of diesel that can have impacts on the quality of unsealed roads.
    - Activity streams related to whole-of-community resilience thinking including aspects of civil infrastructure:
- Repurposing: A process to undertake 'Disaster Repurposing' at a city infrastructure level: In response to calls for a greater level of disaster response facilities, this approach seeks to investigate the potential to harness existing facilities and infrastructure across the city to provide disaster recovery support. The first

stage would focus on a stakeholder led process to identify recovery needs and linking them to potential infrastructure and facilities that could be temporarily repurposed such as the repurposing of existing buildings to offer recovery centres, accommodation shelters, command hubs, energy supply points, warehouses, access to cash, medical services, and wellbeing services; the repurposing of highways as temporary airstrips; the repurposing of alternative logistics options such as shipping; and the repurposing of parks or ovals as camp grounds. The second stage would focus on stakeholder led process to develop a repurposing action plan to include the process to repurpose facilities and infrastructure, the allocation and location of supply caches to support repurposed facilities, the allocation of emergency car parks to assist in repurposing (at potential supply cache locations for instance), and the investigation of the provision of mobile recovery services, especially to isolated communities.

- Strategic tactical planning: A process to increase whole-of-community resilience to natural disasters: The response to natural disasters involves a number of complex tasks that can be informed by prior strategic tactical planning that would focus on stakeholder led processes to develop strategic approaches to building the whole-of-community resilience to natural disasters. The project would consider strategic imperatives such as community evacuation plans (for residents and animals) with specific transport routes and staging areas that are clearly communicated to the community, preparedness checking and remediation of key assets and infrastructure such as critical path transport routes (as in the above project), the continuity of critical services (such as transport, electricity, water, sewerage, and fuel), the continuity of business activities and their role in recover activities, the harnessing of data (as in the above project for road infrastructure) and a process to assess and build the capacity of stakeholders, together with the need for specialised emergency service skills.
    - Activity streams focused on whole-of-community policy actions for resilience to natural disasters:
- Policy 1: Streamlining governance structures to support disaster recovery: A key element of the effective resilience of communities to natural disasters is the existence of governance structures that affect the provision of support for recovery works. This project would focus on two streams, firstly an investigation into opportunities to streamline existing regulations and requirements and remove unnecessary impediments, and secondly an investigation into the opportunity to amend funding structures related to funding rules and requirements, eligibility and access to funding, controls over the use of funding, and the potential for social impact bonds. A key element of this project would be to inform decision making in these areas potentially through site visits and stakeholder interaction by decision makers.
- Policy 2: Culturally appropriate community activation: A key element in natural disaster readiness, response, and recovery is an activated community that is well informed with strong social structures in place. This social capital approach would consider options to support the community through the provision of behaviour change programs (such as those related to setting up disaster kits and stores, or to preparing outdoor areas to be cyclone or flood ready), capacity building sessions (such as on increasing the disaster readiness of homes, ways to increase personal safety during disaster events, and options for volunteer responders to assist with recovery efforts), community events (such as 'Cyclone Sunday' currently run in Townsville to inform residents, or community cyclone practice drills), and street level events (such as a 'Cyclone Ready Streets Program' where relationships are fostered at a street level to increase the resilience to disasters through greater sharing and good will).
- Policy 3: Multi-Agency coordination and communications strategies and practices: Key to a strong response is the coordination and communication between disaster response agencies. This project would be developed in two streams, firstly to investigate options to enhance multi-agency coordination through a focus on the clarification of roles and responsibilities, the development of inter-agency structures and standard operation procedures, undertaking succession planning and capacity building for staff, and the potential for equipment, facilities, and staff sharing. The second stream would investigate multi-agency communication strategies through a focus on the development of standard protocols for communication (including frequencies, technology types, and conversation protocols), a strategic approach to the accurate and timely sharing of information, investigating the potential to harness social media and smart phone applications, and the identification of specific communication needs and audiences to match to appropriate communications platforms, technologies, and message.

3. Conclusion

The stakeholder-based approach to resilience planning from disasters related to transport infrastructure proved to be highly successful. Feedback from participants was highly positive as the outcomes generated above were considered to be innovative and highly practical, filling a need for integrated approaches that had not been considered before. The process proved to be extremely effective at surfacing and gaining widespread support for proposed actions that have the potential to improve the local resilience to natural disasters. The results of the workshop have subsequently been discussed with senior staff from the relevant State-level departments who were particularly impressed by the rigorous nature of the investigation and subsequent analysis. This allowed these staff to integrate the ground level perspectives with their own strategic agenda and, in turn, it is anticipated that this will lead to requirements to undertake more detailed studies of key areas.

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