Knowing maintenance vulnerabilities to enhance building resilience

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Resilient buildings: Informing maintenance for long-term sustainability

SBEnrc Project 1.53

Project participants

Chair: Graeme Newton

Research team

- Swinburne University of Technology
- Griffith University

Industry partners

- BGC Residential
- Queensland Dept. of Housing and Public Works
- Western Australia Government (various depts.)
- NSW Land and Housing Corporation

An overview

- Project 1.53 – Resilient Buildings is about what we can do to improve resilience of *buildings* under *extreme events*
- *Extreme events* are limited to high winds, flash floods and bushfires
- *Buildings* are limited to state-owned assets (residential and non-residential)
- Purpose of project: develop recommendations to assist the departments with policy formulation
- Research methods include:
  - Focused literature review and benchmarking studies
  - Brainstorming meetings and research workshops with research team & industry partners – e.g. to receive suggestions and feedbacks from what we have done so far

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Australia – in general

- 6th largest country (7617930 Sq. KM)
  - 34218 KM coast line
  - 6 states
- Population: 25 million (approx.)
  - 6th highest per capita GDP
  - 2nd highest HCD index
  - 9th largest immigrant population

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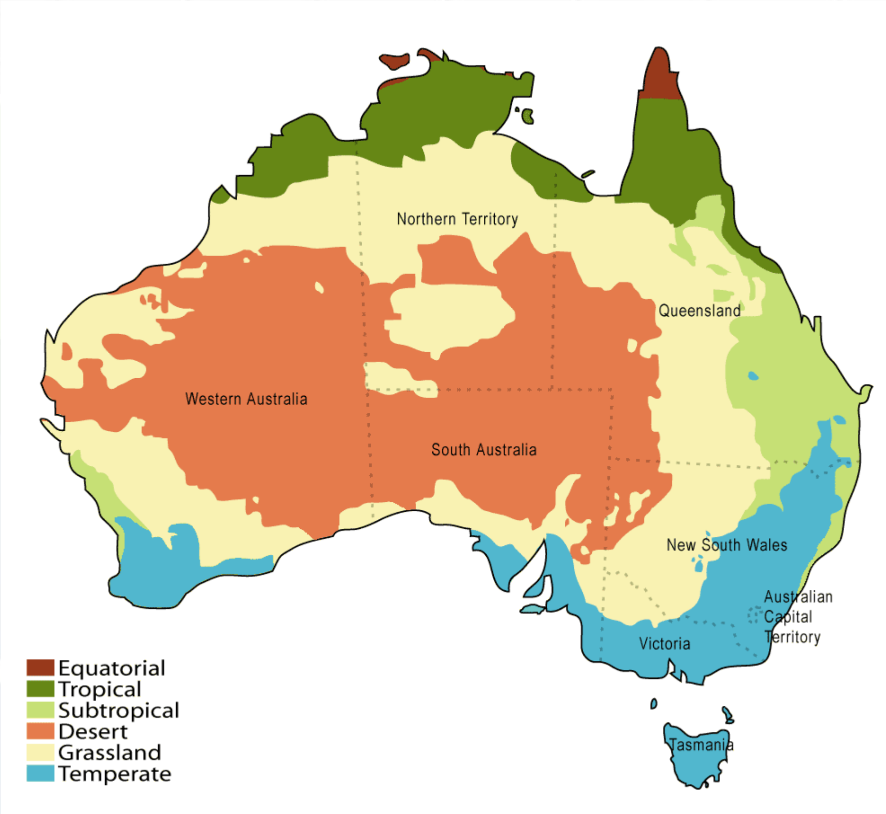
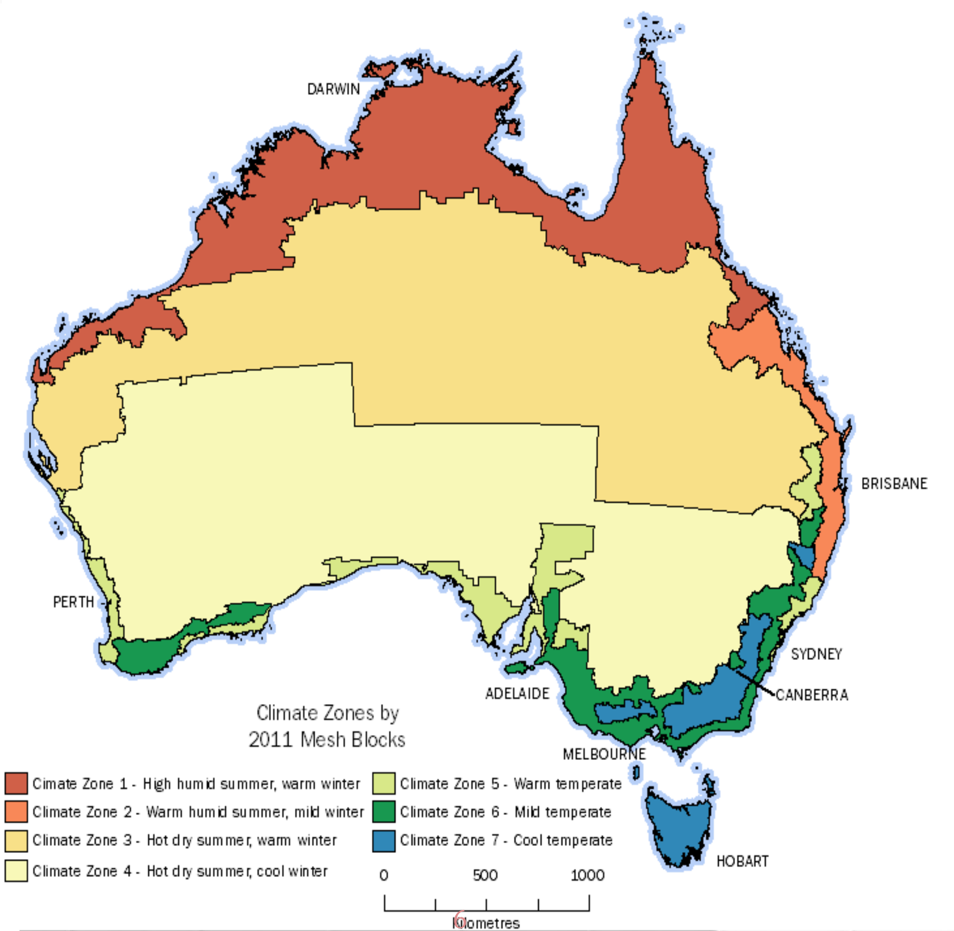
Natural Disasters - Diverse complexities & many uncertainties…





Extreme events in Australia – E.g. Cyclones

State	Event Name	Event Date	Estimated Loss Value (2015)
QLD, NSW	Cyclone Debbie	March 2017	$1,403,000,000*
NSW, QLD, VIC, TAS	East Coast Low	June 2016	$421,696,229
NSW	East Coast Low	April 2015	$949,615,700
QLD	Severe Tropical Cyclone Marcia	February 2015	$544,163,458
VIC	Melbourne Severe Storm	February 2011	$526,651,637
QLD	Cyclone Yasi	February 2011	$1,531,573,196
QLD	Cyclone Tasha	December 2010	$393,000,000
NSW	East Coast Low	June 2007	$1,675,000,000
QLD	Cyclone Larry	March 2006	$799,000,000
QLD	Cyclone Justin	March 1997	$650,000,000
NSW	Sydney Region Storms	January 1991	$625,000,000
WA	Cyclone Joan	December 1975	$398,000,000
NT	Cyclone Tracy	December 1974	$4,090,000,000
QLD	Cyclone Althea	December 1971	$648,000,000
QLD	Cyclone Ada	January 1970	$1,001,000,000
QLD	Cyclone Dinah	January 1967	$877,700,000

*Original estimated insurance loss value

Source: http://www.icadataglobe.com/access-catastrophe-data/

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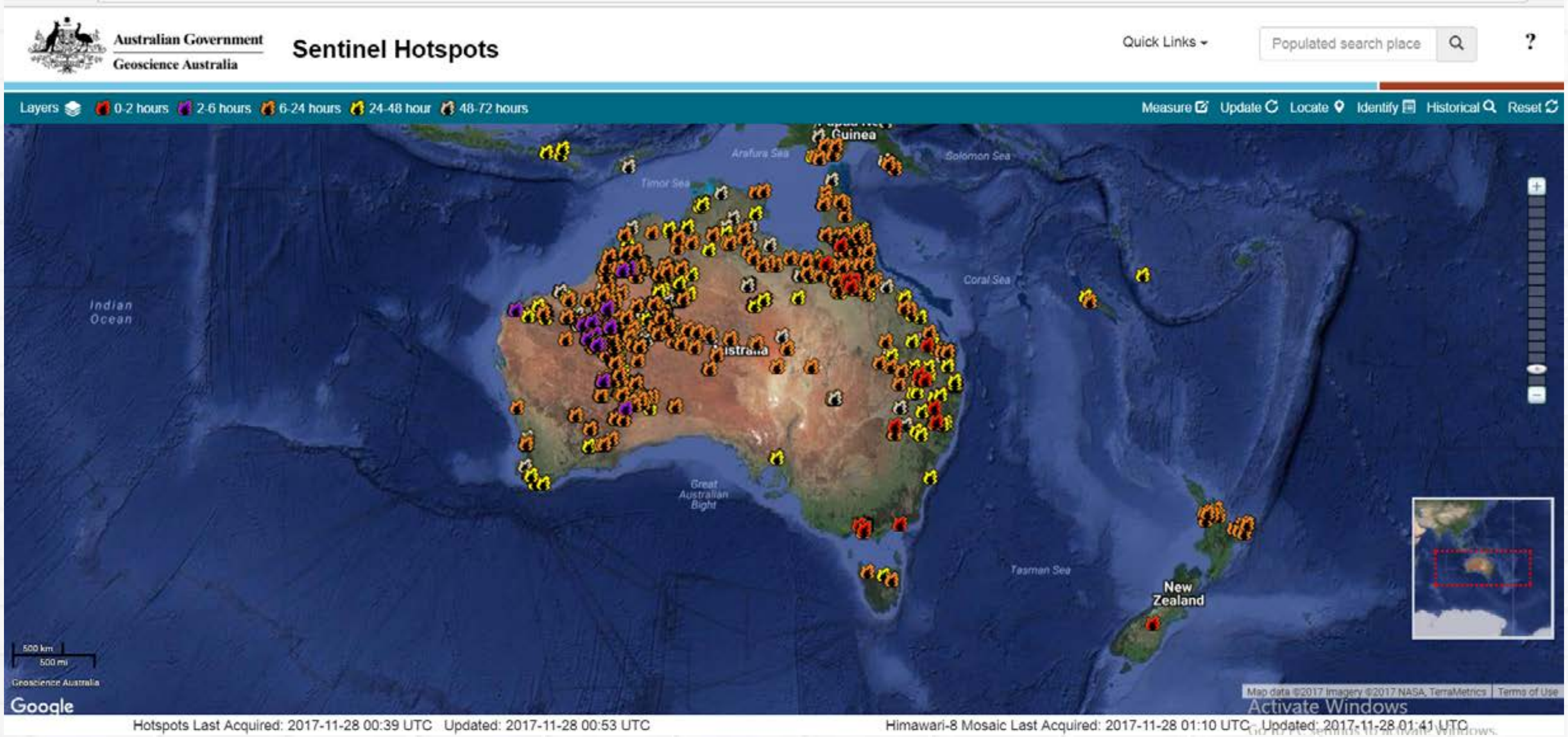
Dynamic Information – e.g. Sentinel hotspots



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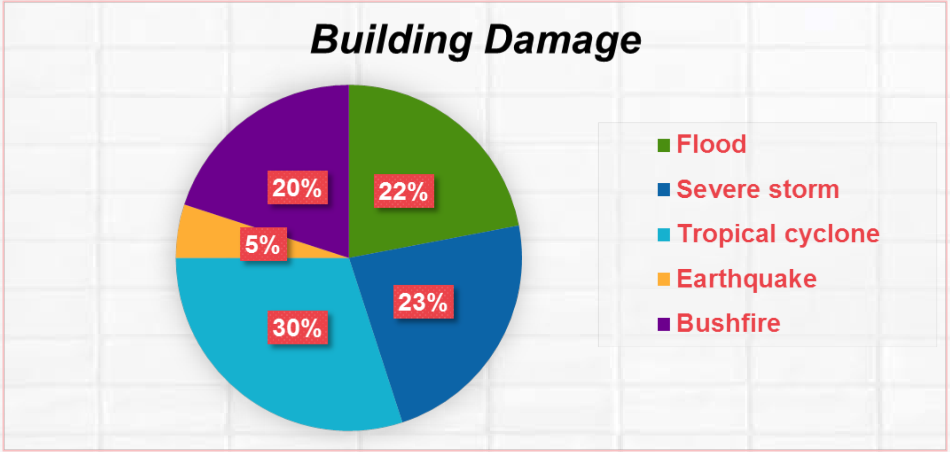
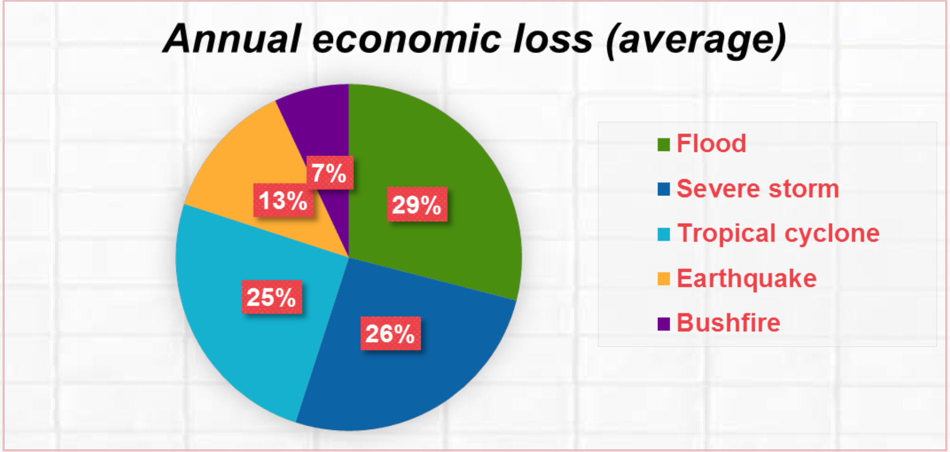
Impacts of extreme events in Australia





32-year period from 1967 to 1999 as per BTE (2001)

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A snapshot of losses by region in Australia

Category of extreme event	New South Wales	Northern Territory	Queensland	South Australia	Victoria	Western Australia
Flood	26.2%	5.7%	46.7%	39.2%	41.1%	4.1%
Severe storm	40.5%	---	15.6%	35.1%	24.3%	17.7%
Tropical cyclone	---	94.1%	0.2%	---	---	66.4%
Earthquake	29%	---	---	---	---	4.7%
Bushfire	3.5%	---	37.6%	25.8%	34.6%	7.1%

32-year period from 1967 to 1999 as per BTE (2001)

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Disaster Resilience in Australia

- Policy papers & frameworks by Australian Government
  - e.g. National Strategy for Disaster Resilience, National Disaster Resilience Framework
- Design standards for buildings subjected to extreme events of a specific hazard
  - e.g. AS/NZS 1170.2:2011 for wind actions, AS/NZS 1170.4–2007 for earthquake actions, AS3959-2009 for construction in bushfire-prone areas and National Construction Code for flood actions.

ASCE SmartBrief newsletter (dated 15th September 2017): "Stronger building codes might improve building resilience and potentially limit damages from extreme events, e.g. hurricane Irma and severe storms"

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Targeted project deliverables

Our current project P1.53 has following target & scope:

- Resilience for **high winds** (Griffith – Rodney lead);
- Resilience for **flash floods** (Swinburne - Palaneeswaran lead), and
- Resilience for **bush fire** (Swinburne - Lam lead)

Each sub-project produces linked reports related to the three core deliverables:

Deliverable 1: Current state of knowledge: existing preventative maintenance practice, failures due to lack of maintenance etc. for the relevant extreme event.

Deliverable 2: Identification of critical preventative maintenance issues for the relevant extreme event (including inventory of vulnerable building stock typologies).

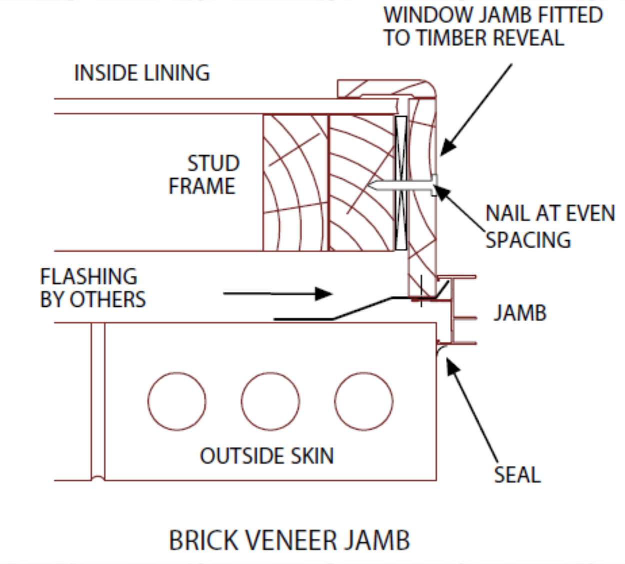
Deliverable 3: Implementation strategies – regulatory and non-regulatory means (i.e. policy/practice recommendations for governments, building asset managers and owners, insurance institutions, etc.)

Wind-driven rain and public housing envelope (GU feed)

- Improving resilience of public housing to non-structural damage from wind-driven rain due to extreme weather events (i.e. cyclone and severe storms)

- Focus on resilient design and enhanced construction inspection; specifically waterproofing standards of the building envelope (**AS4654**), windows and doors (**AS2047**) and Masonry (**AS4773**)

- In-depth inspection for building envelopes in regions vulnerable to cyclones (checklists)



Window and roof failure modes

Building elements	Failure Modes	Damage through components
Window	Material / design	through louvre windows
		through undamaged windows
		through open gaps between sashes, frames and through seals
		through worn or damaged window seals
		around flashings, through linings
		through weep holes, gaps and around seals
	Bad installation / material/ design	through the window frame
Roof	Material / design	eaves, gutter, gables
	Bad installation / material/ design	under flashings, gutters, eaves lining

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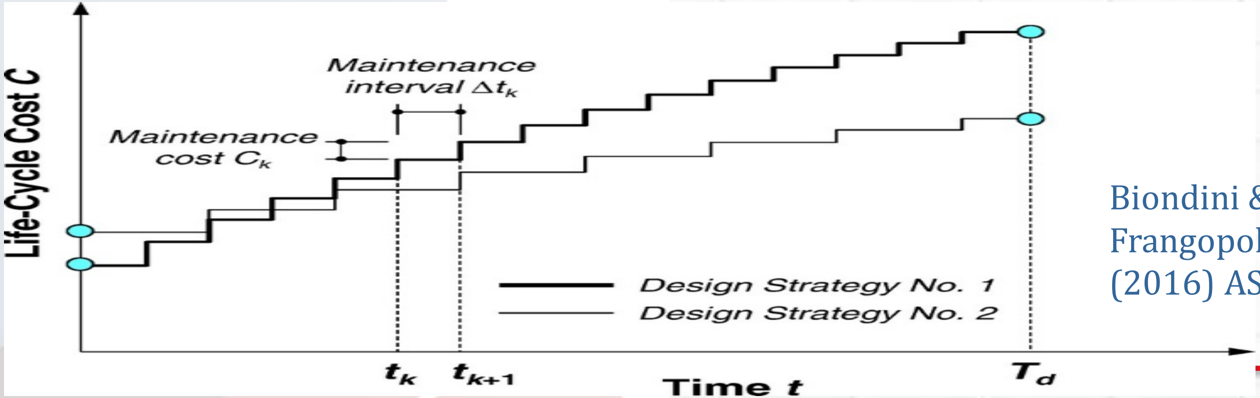
Hardening options – low hanging fruit

- Focused on recommending some hardening opportunities that represent the best life cycle cost-benefit (e.g. window/door specification and inspection) for low density public housing
- Estimate life cycle cost for scenario of reduced incidence of non-structural wind and water ingress related damage due to extreme wind events for both the recommended strategies and BAU approach
- Determine the life cycle cost-benefit of the proposed resilience hardening strategy for critical building components in regions vulnerable to extreme wind events



Biondini & Frangopol (2016) ASCE

Maintenance for Resilience

Creative Commons Figure source: http://1.bp.blogspot.com/-BJtFLUQxFnc/UBX6ZZbLpAI/AAAAAAAATVg/yW5js-3BJWg/s1600/JNB_7198.JPG

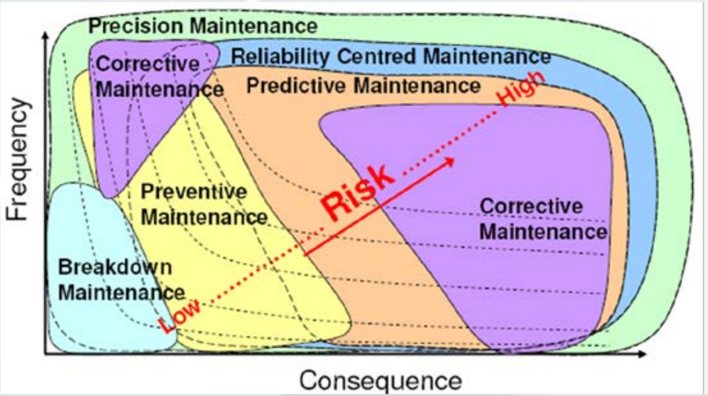


Figure source: www.lifetime-reliability.com

- Risk based approach
- Whole-life resilience
- Cost (or Value) vs Benefit
- PESTEL analysis
- Regulatory governance & non-regulatory best practices
- Benchmarks & measures
- Classification & Priorities
- Frameworks for Inspecting, Monitoring, Controlling, and Auditing
- Opportunities for Redesign, Repair & Retrofit for better

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Summary of Observations & Persuasion

- Extreme events (e.g. cyclones, bushfire, flash floods) cause considerable damage to buildings and incur enormous repair costs
- Non-structural failure of certain weak building elements (e.g. roof sheeting fixings) leads to costly damage (e.g. water ingress) – *prevention can be less costly than repair/ mitigation in many cases*
- Existing building inspection & maintenance largely unregulated, and where undertaken has limited focus on resilience
- Building inspectors review public buildings on a predefined basis; however, consideration for extreme event vulnerability and resilience hardening is not adequately considered
- Opportunity to improve current regulatory and non-regulatory regime for resilience related maintenance (both residential and non-residential)

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An overview of key gaps

- Limited risk consideration in regulation
- Emerging risks & ripple effects
- Regulatory difficulties in handling durability risks
- Understanding of the nature of extreme events
- Understanding the vulnerabilities of buildings
- Coordination between responsible bodies
- Lack of as-built information on buildings

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Feasibilities include…

- On new buildings (best opportunity)
  - Need to think beyond what are required by current regulation
  - Design for maintenance: make provisions for maintenance, provide guidance for maintenance
- On existing buildings:
  - Early detection with regular inspection
  - Risk assessment for specific categories
  - Rethinking rules & rationalising priorities
  - Guidance for maintenance with as-built information

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Questions, Discussions & Collaborations?

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https://sbenrc.com.au/research-programs/1-53/