Hardening Building and Infrastructure Cluster

PROJECT A9: Cost-effective mitigation strategy development for building related earthquake risk

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

bnhcrc.com.au

Project Participants

Univ of Adelaide:

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Swinburne University:

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Geoscience Australia:

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End Users:

WA DFES, York Shire Council, ABCB, Standards Australia, EMA, State/Local Governments

Aim: to develop evidence base to inform decision making for earthquake risk mitigation

- ✓ **Establish seismic vulnerability classes for representative building types in Australia**
- ✓ **Survey existing retrofit techniques for known performance in recent earthquakes**
- **Develop cost-effective Australia-specific retrofit solutions**
- **Develop decision-support and earthquake risk forecasting tools to support infrastructure managers**
- **Develop economic loss models that include business interruption and casualty costs**

Australian building stock vulnerability classification (completed).

Building classification parameters

- Usage,
- Construction Period,
- Proximity to Coast,
- Primary Lateral Load Resisting System,
- Storey Height Range,
- Wall Type,
- Wall Material,
- Roof Material.

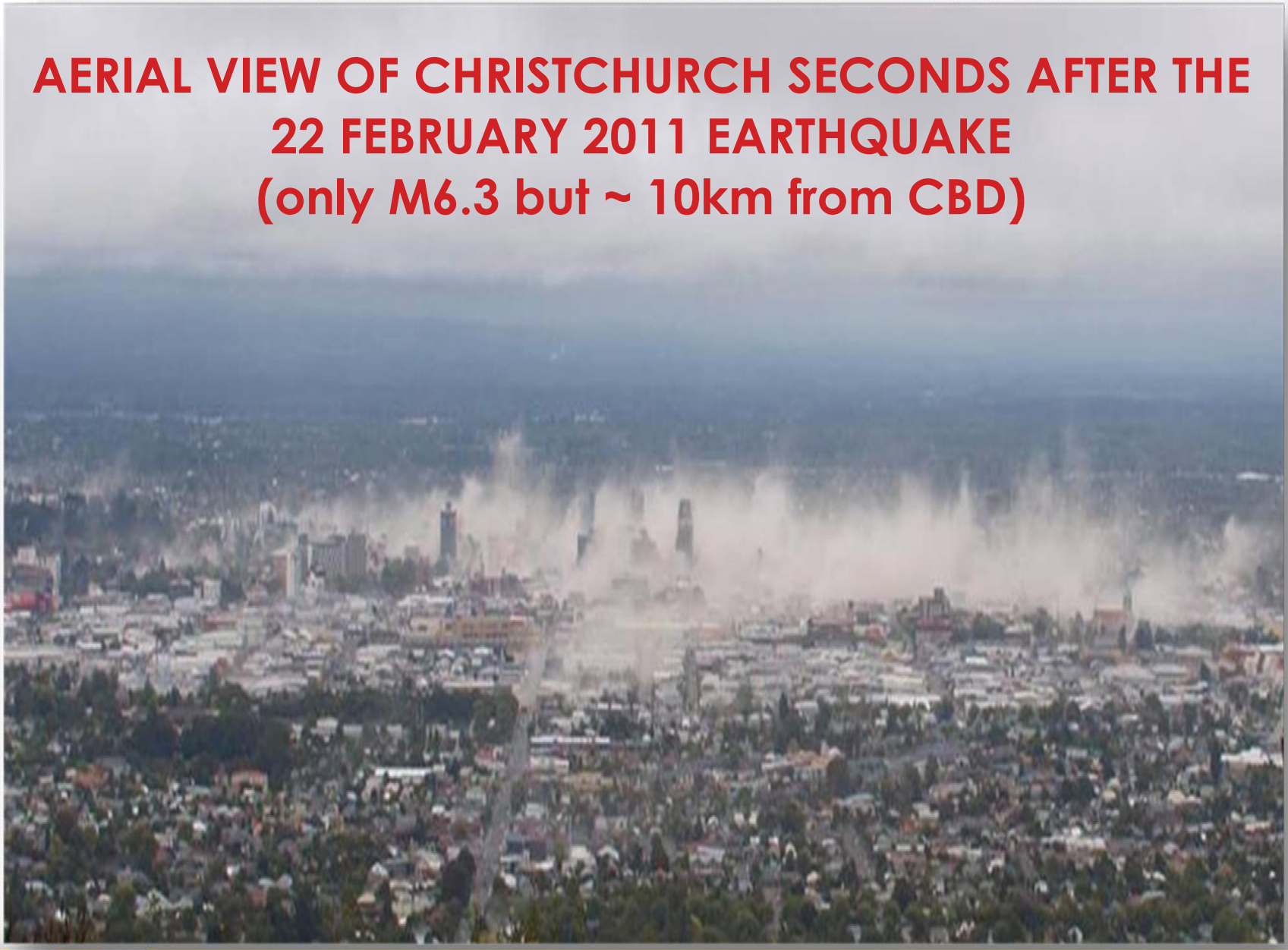

Cost-Effective Mitigation Strategy Development for Building Related Earthquake Risk

Preliminary Building Schema

New/Improved Retrofit Options (6/6 completed)

1. *Rank Vulnerability of Common Construction Types*
2. *Identify Failure Modes of High Risk Construction Types under Seismic Loading*
3. *Identify Available Retrofit Techniques for High Risk Construction Types*
4. *Use Christchurch Data to Identify Successful Retrofitting Techniques (~ 600 building database)*
5. *Use Christchurch Data to Identify Unsuccessful Retrofitting Techniques and Investigate Possible Improvements*
6. *In-situ tests of 11 walls and 3 chimneys in 3 URM houses in Adelaide.*

AERIAL VIEW OF CHRISTCHURCH SECONDS AFTER THE 22 FEBRUARY 2011 EARTHQUAKE (only M6.3 but ~ 10km from CBD)



Lessons from Christchurch

Christchurch corner shops

Adelaide corner shops

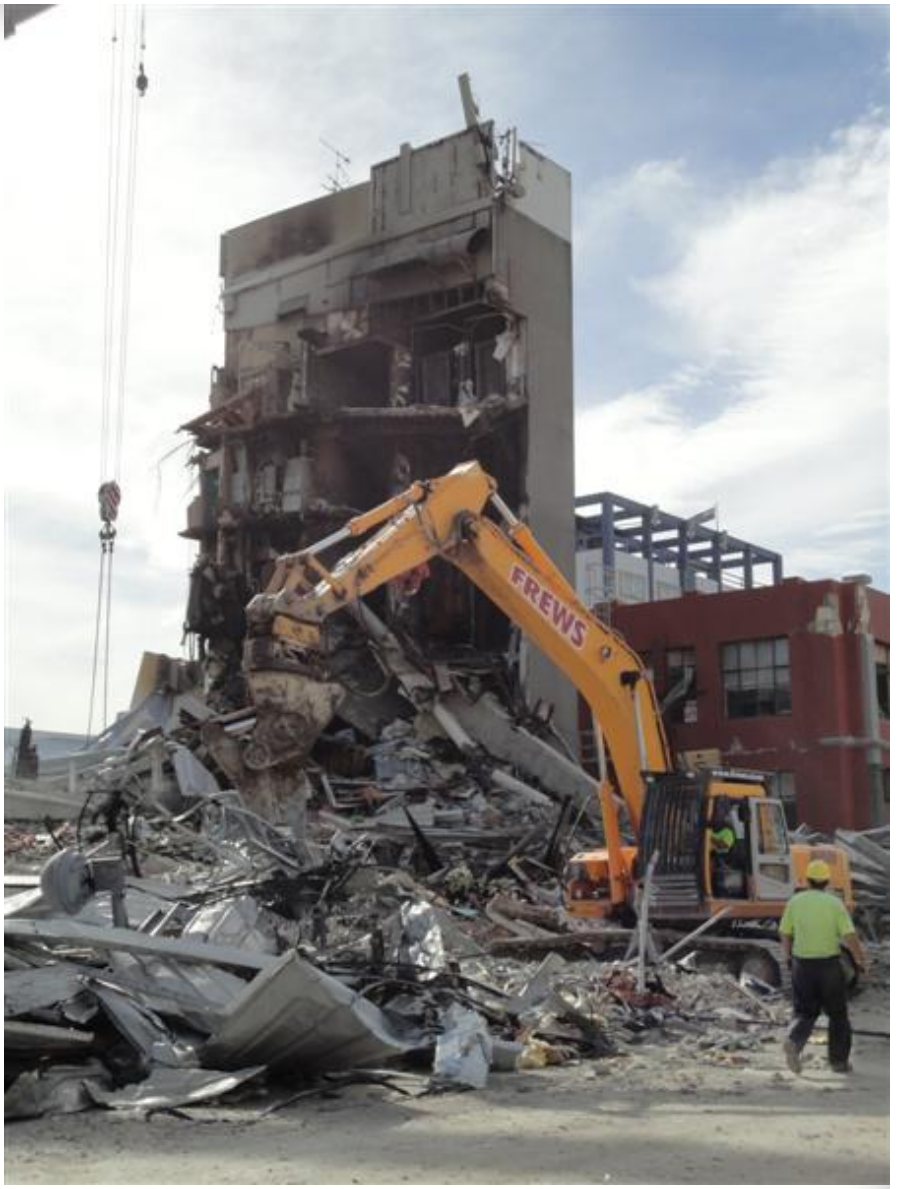
Christchurch theatre

Adelaide arcade

Out-of-plane wall bending failures in Unreinforced Masonry (URM) buildings in Christchurch (42 fatalities)

Failure of reinforced concrete buildings in Christchurch

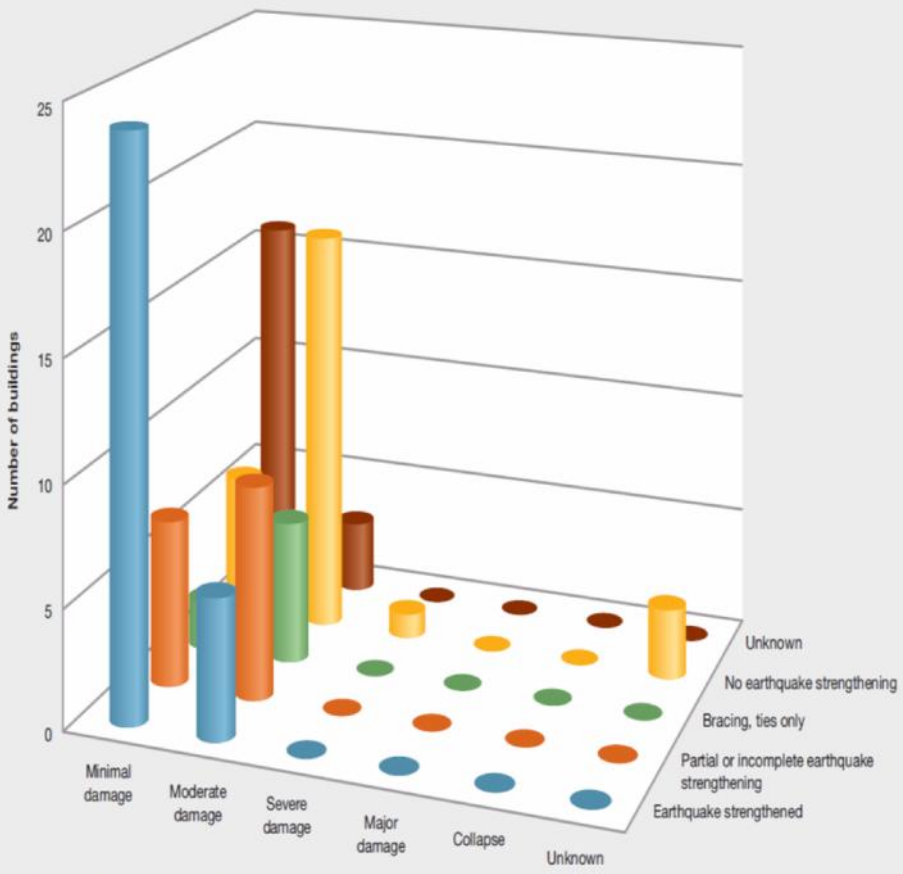
PGC – 18 fatalities



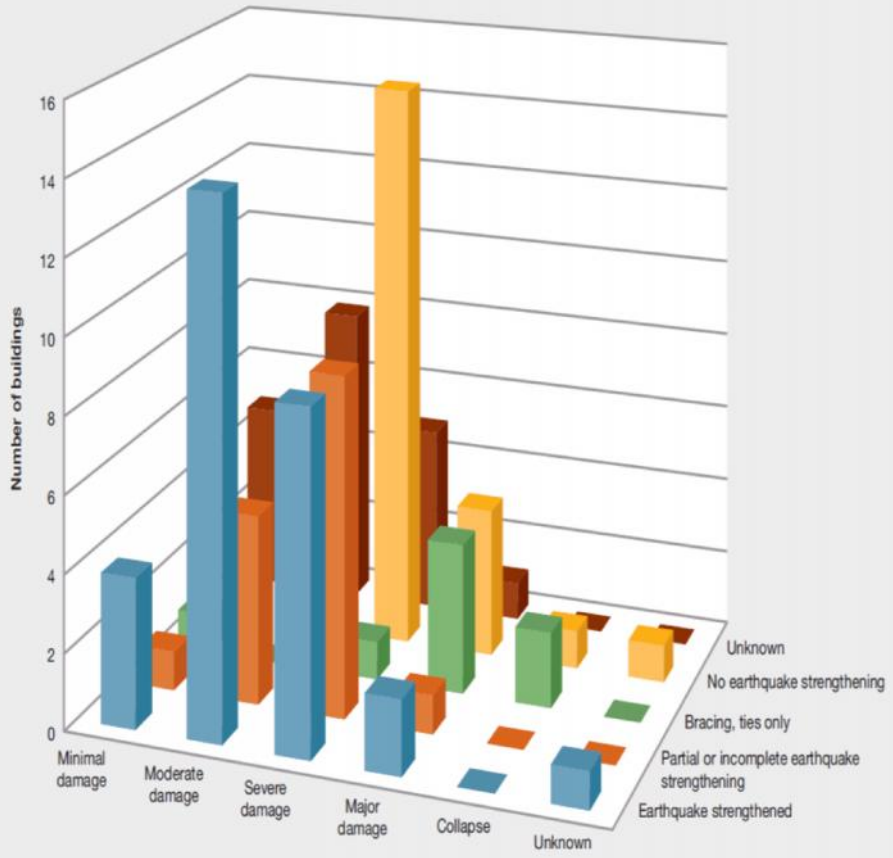
CTV – 115 fatalities

DAMAGE REDUCTION DUE TO SEISMIC STRENGTHENING

1) Sept – Dec 2010

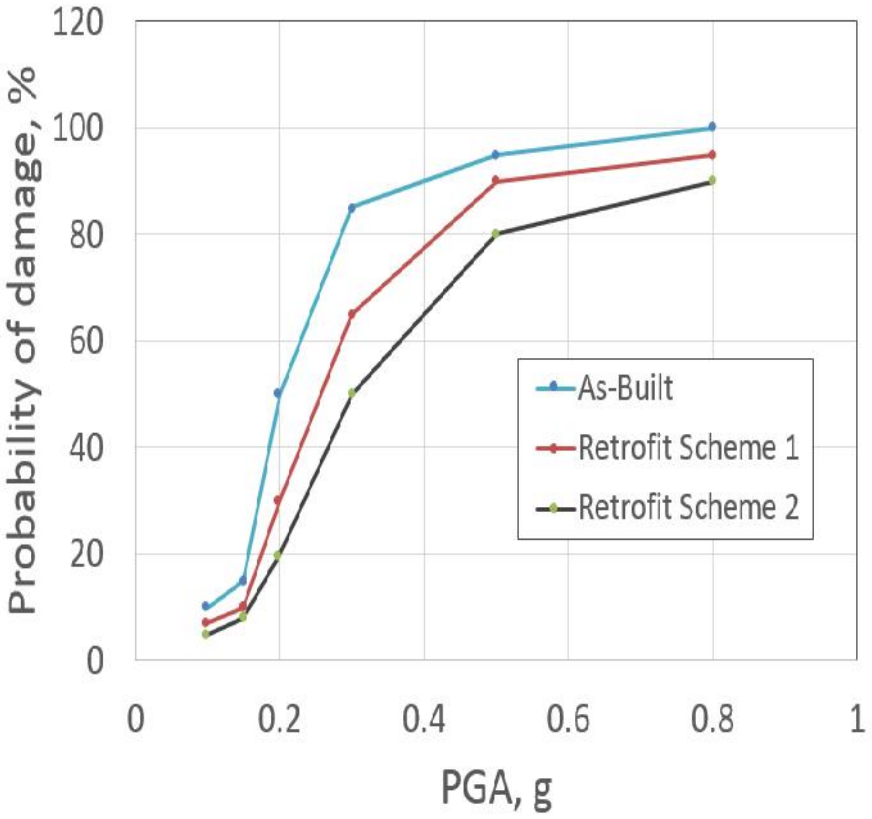


1) Jan – July 2011

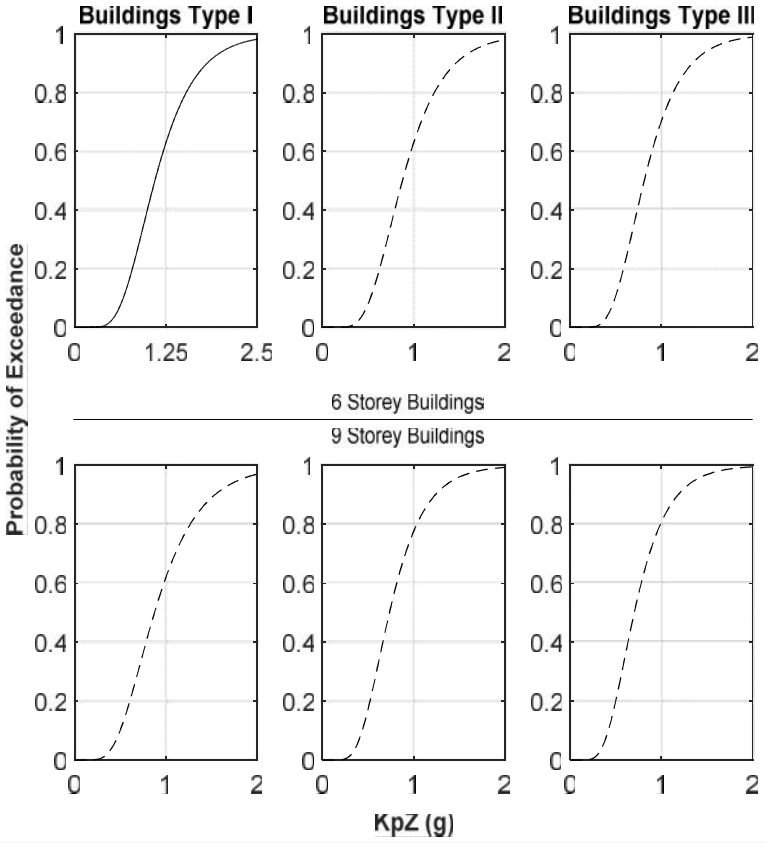


SEISMIC VULNERABILITY CURVES

1) URM



1) Reinforced Concrete

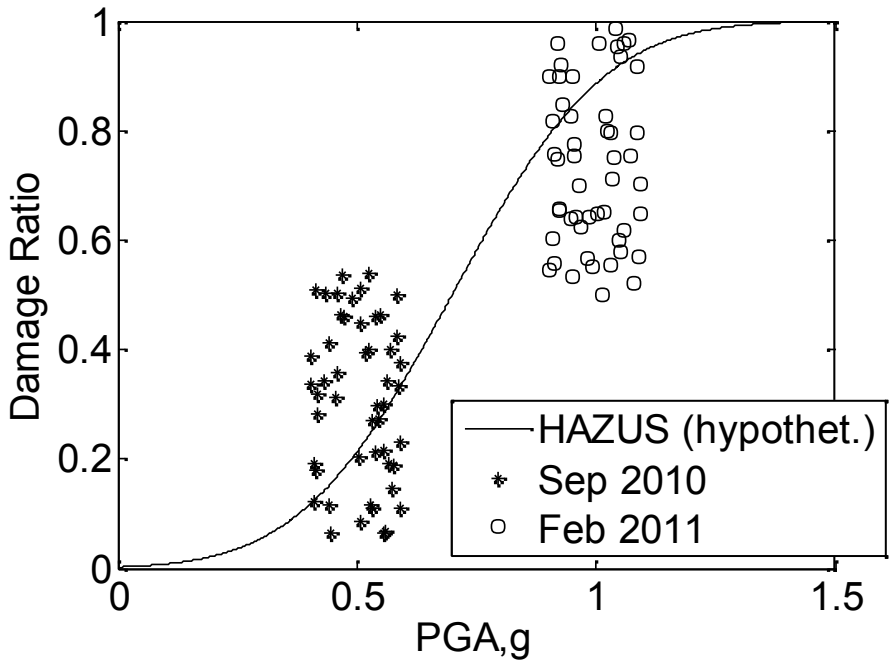


FRAGILITY CURVES FOR URM BUILDINGS

- Base fragility models from existing literature, e.g.

  - Applied Technology Council (ATC-58)
  - FEMA (HAZUS-MH)
  - D'Ayala et al. 2014

- Canterbury earthquake data are used to develop the curves



A hypothetical fragility curve from HAZUS fitted to empirical data

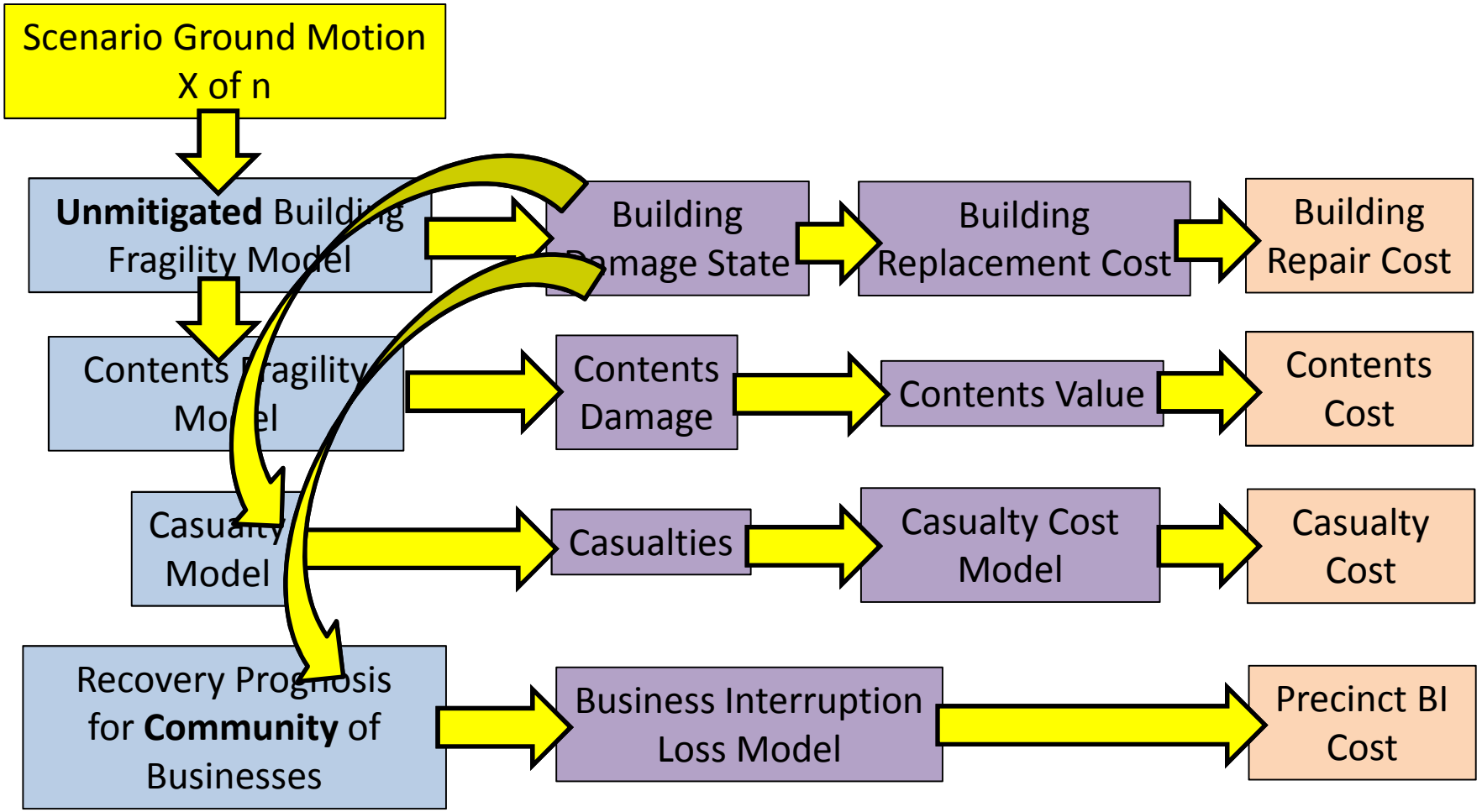
Damage & Economic Loss Modelling

1. *Rank Vulnerability of Common Construction Types*
2. *Estimate Structural Drift for Various Magnitude Events*
3. *Develop Damage-Drift Relationships to Estimate Building Damage*
4. *Develop Cost-Damage Relationships to Estimate Economic Impact* of Natural Hazard*

- *costs to include fatalities & injuries, business interruption at a precinct level*

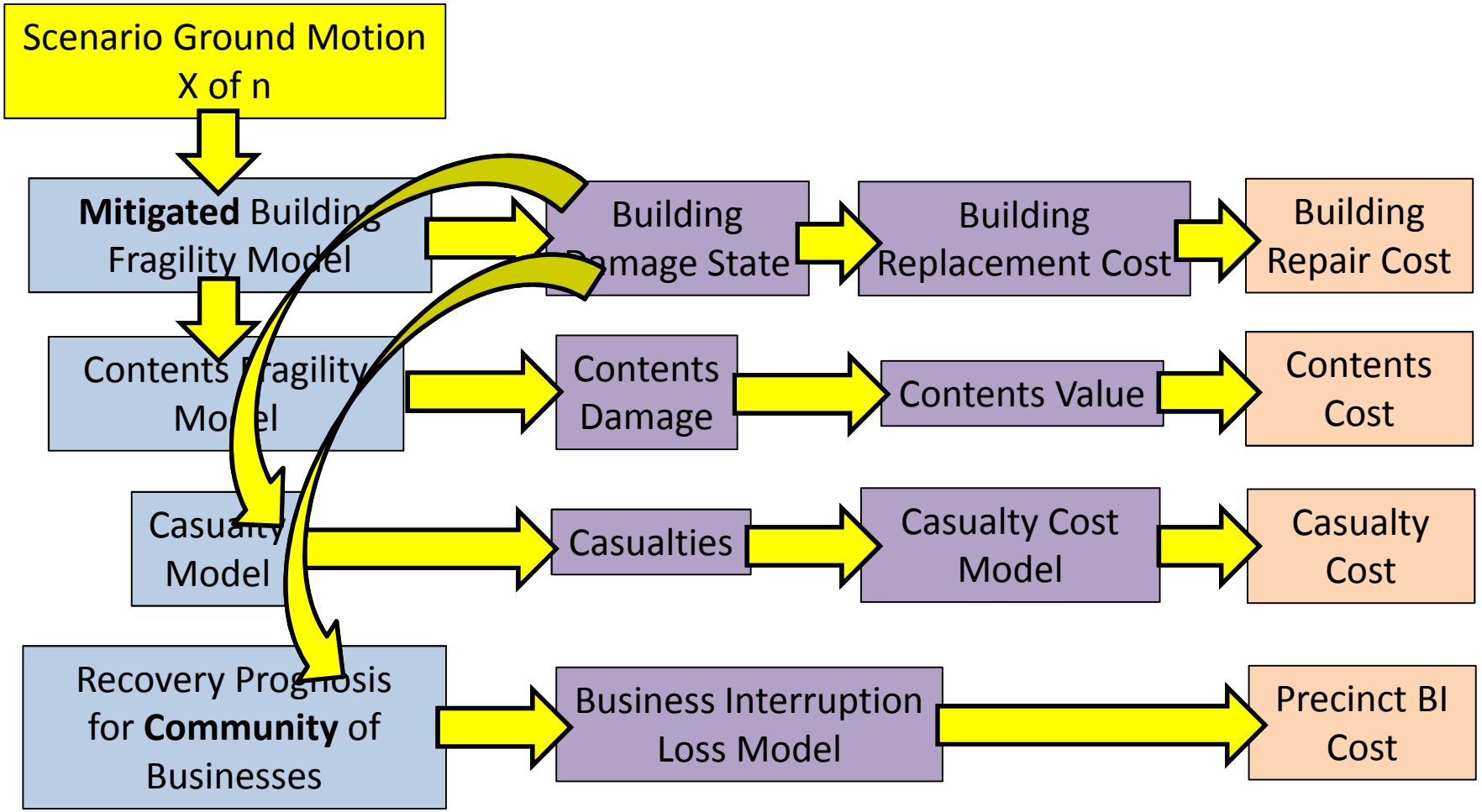
1, 2 ‘done’; 3 in progress; 4 ???

Precinct Modelling Logic - Unmitigated Baseline



Total Unmitigated Precinct Loss for Scenario X =

Precinct Modelling Logic - Mitigated Shift



Total Mitigated Precinct Loss for Scenario X =

ECONOMIC EVALUATION

Annualised Long Term Loss for Hazard Exposure:-

- Integrate total unmitigated losses for all likelihoods to determine annualised loss without action.
- Integrate total mitigated losses for all likelihoods to determine annualised loss with mitigation action.

Annual Benefit of Mitigation:-

- Subtract annualised unmitigated loss from mitigated case to determine benefit

Benefit Versus Investment Cost of Mitigation:-

- Discount the annual savings realised through mitigation to PV
- Divide PV of savings by retrofit cost to obtain B/C

Expected Outputs (as stated in proposal):

- **A cost-benefit analysis methodology for key retrofit options at both the building and regional levels**

- **Information and models to enable planning authorities to develop policies and legislation, backed up by substantiated economic benefits**

Closing Remarks

- Design magnitude earthquakes (1 in 500 yr) will affect large area (~ 30km radius)
- While the earthquake Hazard is low, the Risk (= probability x exposure) is high - a M6 earthquake in Sydney is ranked in the top 10 of financial risks for the world's reinsurance industry!
- Damage will be widespread and take many years to repair – Christchurch damage ~ 20% GDP and at least 10 years to repair!
- We continue to seek engagement with our end users where they exist and recruitment of new end users where they are missing to facilitate national 'take-up' of our research outputs/recommendations.

UTILISATION ROADMAP 1

CLUSTER NAME: Hardening Building and Infrastructure Cluster

PROJECT NAME: Cost-effective mitigation strategy development for building related earthquake risk

- **What need is being addressed?**

Shortage of a rapid screening tool to identify buildings with deficiency in their seismic resistance for a more detailed check

- **What is the utilisation product?**

A Visual Screening Procedure

- **What difference will this utilisation make?**

The project will enable the earthquake-prone buildings in Australian communities to be swiftly identified, hence the typically limited funds for seismic retrofit, whenever available, to be rationally distributed.

- **Who wants it?**

State/Local governments, Emergency Management Australia.

UTILISATION TITLE: Rapid Visual Screening (RVS) Procedure

What is it: Checklists for the rapid assessment of the structures that may be prone to earthquakes.
Who is it for: Primarily building owners but also for Insurance Industry, Emergency Services, and governments; State governments, e.g. SA, are increasingly requiring existing buildings to undergo a rapid assessment, especially if the owner applies for a permit for significant changes
Why will it matter: It is impractical to require all buildings to undergo lengthy and costly detailed seismic assessment, and several countries have rapid procedures available nationally for this purpose.

Key Research Milestones

* Final Report on Fragility Curves for LDRC Buildings
* Final Report on Fragility Curves for URM Buildings
* Final Report on Retrofit Methods for LDRC Buildings
* Fragility Curves for Retrofitted URM Buildings

Key Utilisation Activities

* Literature Review (global and local RVSs)
* Generic weakness identification and scoring system development
* Classification of buildings with respect to a scoring system
* Generic fragility curves for classes of building
* Development of earthquake vulnerability index
* Case studies

Key Utilisation Milestones

* End user meeting
* Preliminary report
* Final Checklists for RVS

Dec 17 | Jun 18 | Dec 18 | Jun 19 | Dec 19 | Jun 20

Who is doing it?
University of Adelaide
University of Melbourne
University of Swinburne

Who needs to be involved?
State Governments
Emergency Management Australia
Steel Reinforcement Institute of Australia
Concrete Institute of Australia

What are the key challenges?
Different State Governments may have existing procedures that are not informed by research
Internationally documented weak links in seismic load path within buildings may not fully address Australian construction due to the seriousness of earthquake having long been underestimated despite the risks.

What will it cost?
30k

UTILISATION ROADMAP 2

CLUSTER NAME: Hardening Building and Infrastructure Cluster

PROJECT NAME: Cost-effective mitigation strategy development for building related earthquake risk

- **What need is being addressed?**

The net cost of the proposed changes to Australian Earthquake Loading Code for incorporating new improved Australian earthquake hazard knowledge.

- **What is the utilisation product?**

Regulatory Impact Assessment for the Proposed Minimum Threshold Design Earthquake Actions.

- **What difference will this utilisation make?**

It will promote a more rational earthquake design of buildings reflecting the actual earthquake hazard. It also will help preventing catastrophic loss of life in a rare earthquake.

- **Who wants it?**

Australian Building Codes Board.

UTILISATION TITLE: Holistic Risk Assessment of Regulatory Requirements for Earthquake Design

What is in it: Regulatory Impact Statement that clearly articulate the net cost of the proposed changes to Australian Earthquake Loading Code for incorporating new improved Australian hazard knowledge
Who is it for: Australian Government, Australian Building Codes Board (ABCB), and ultimately building owners and also insurance industry
Why will it matter: The ABCB will be able to assess the net increase in construction costs, if any, due to incorporating the new Australian seismic hazard map. This evidence of economic impact is required before the new, more rational, seismic loading requirements can be implemented.

How will it be done?

Key Research Milestones

* Final Report on Fragility Curves for LDRC Buildings
* Final Report on Fragility Curves for URM Buildings
* Final Report on Retrofit Methods for LDRC Buildings
* Fragility Curves for Retrofitted URM Buildings

Key Utilisation Activities

* Documentation of 3 indicator buildings
* Structural analysis of the buildings for different levels of seismicity
* Costing and articulating the net cost of the proposed changes to AS 1170.4
* Developing a Regulatory Impact Statement (RIS) for Indicator Buildings
* Structural design and costing for rarer seismic events
* Structural design and costing for collapse prevention

Key Utilisation Milestones

* Stage 1 Report for RIS Indicator Buildings
* Stage 2 Report on National Construction Cost Change
* Final Report on Economic Inputs into RIS
* Report on Economic Implications of Rarer Design Loads for New Construction
* Report on Regulatory Effectiveness in Collapse Prevention in Australian Seismicity

Dec 17 | Jun 18 | Dec 18 | Jun 19 | Dec 19 | Jun 20

Who is doing it?
Geoscience Australia
Universities of Melbourne, Adelaide and Swinburne
Australian Building Codes Board (ABCB)

Who needs to be involved?
Australian Building Codes Board (ABCB)
Steel Reinforcement Institute of Australia (SRIA)
ThinkBrick
Concrete Institute of Australia (CIA)

What are the key challenges?
Data defining the value of new building construction and their form nationally.
Quantifying the incremental increased cost of new construction to higher design levels.
Understanding the collapse behaviour of key Australian building types.

What are the key opportunities?
To inform the optimal use of finite construction resources in Australia.
To inform the minimisations of the chances of catastrophic loss of life in an earthquake

What will it cost?
Within budget + 45k from ABCB

UTILISATION ROADMAP 3

CLUSTER NAME: Hardening Building and Infrastructure Cluster

PROJECT NAME: Cost-effective mitigation strategy development for building related earthquake risk

- **What need is being addressed?**

Case Study of Mitigation Strategy Implementation in CBD of the Historic Towns of York and Northam, WA.

- **What is the utilisation product?**

Options for Seismic Retrofit of Buildings Will be Proposed and a range of implementation strategies developed with the local and state government explored.

- **What difference will this utilisation make?**

It will inform WA State and Local Government policy to advance mitigation of the high earthquake risk of some WA communities

- **Who wants it?**

Department of Fire and Emergency Services, WA.

York Shire Council

UTILISATION TITLE: Earthquake Mitigation Case Studies for WA Regional Towns

What is in it: Benefits gained from one or more retrofit scenarios applied to URM buildings in two historic towns in WA
Who is it for: WA Government but also beneficial to Insurance industry and building/business owners
Why will it matter: The two historic towns have a predominance of older URM buildings and progressive retrofit of the buildings will reduce the risk posed to WA State.

How will it be done?

Key Research Milestones

* Final report on fragility curves for URM buildings
* Fragility curves for retrofitted URM buildings
* Report on economic evaluation of mitigation strategies at building level

Key Utilisation Activities

* Building exposure data from NEXIS augmented by field survey activity
* Business exposure is defined
* Fragility attribution for heritage URM buildings in CBD
* Formulation of a range of heritage-sensitive seismic retrofit strategies
* Cost-benefit analysis of seismic retrofit

Key Utilisation Milestones

* Meetings with stakeholders including Emergency Management officials
* Community engagement
* Field Demonstration for End Users of URM Retrofit Methods
* Report on Scenario Modelling and Economic Analysis
* Final report on Case Study CBD Precinct

Dec 17 | Jun 18 | Dec 18 | Jun 19 | Dec 19 | Jun 20

Who is doing it?
Geoscience Australia
University of Adelaide
Department of Fire and Emergency Services, WA

Who needs to be involved?
State Governments
Masonry industry
Heritage building societies

What are the key challenges?
Access to buildings and equipment for field testing
Industry support for applying seismic retrofit

What are the key opportunities?
Field demos give high profile PR for project and CRC

What will it cost?
Within original budget + GA support