bushfire&natural HAZARDSCRC

RESILIENCE & MITIGATION THROUGH HARDENING THE BUILT ENVIRONMENT (BUILDINGS & INFRASTRUCTURE)

A9: Cost-effective mitigation strategy for Earthquake Risk

Professor Michael Griffith
School of Civil, Environmental & Mining Engineering, The University of Adelaide

An Australian Government Initiative

CRC AUSTRALIA

A9: COST EFFECTIVE MITIGATION STRATEGY FOR BUILDING-RELATED EARTHQUAKE RISK

Project Participants

Univ of Adelaide:

MC Griffith, M Jaksa, P Visintin, W Lucas

Univ of Melbourne:

NTK Lam, H Goldsworthy, E Lumantarna

Swinburne University:

JL Wilson, E Gad, HH Tsang

Geoscience Australia:

M Edwards, H Ryu, M Wehner

Lessons from Christchurch

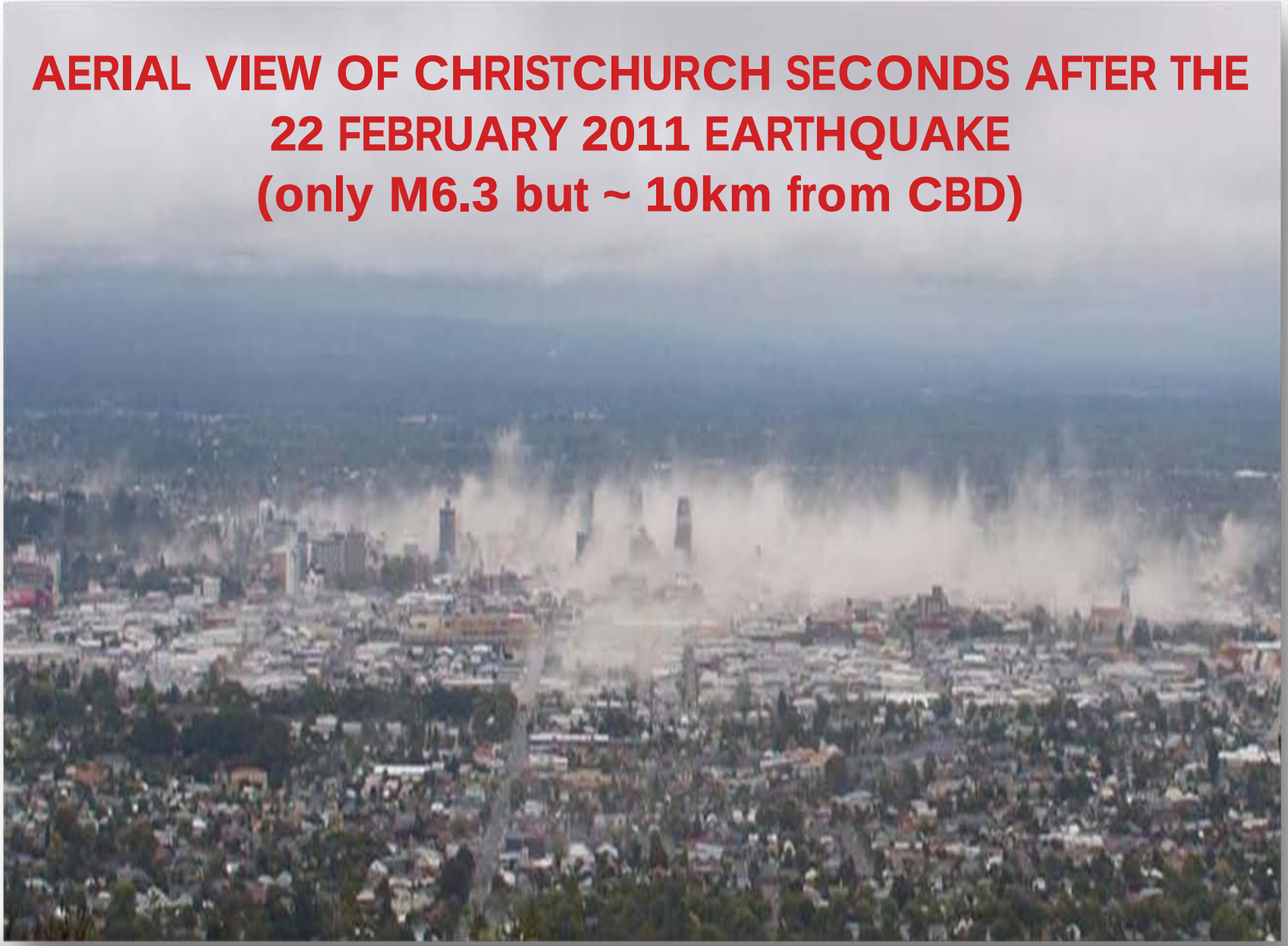
Christchurch corner shops

Adelaide corner shops

Christchurch theatre

Adelaide arcade

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



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

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

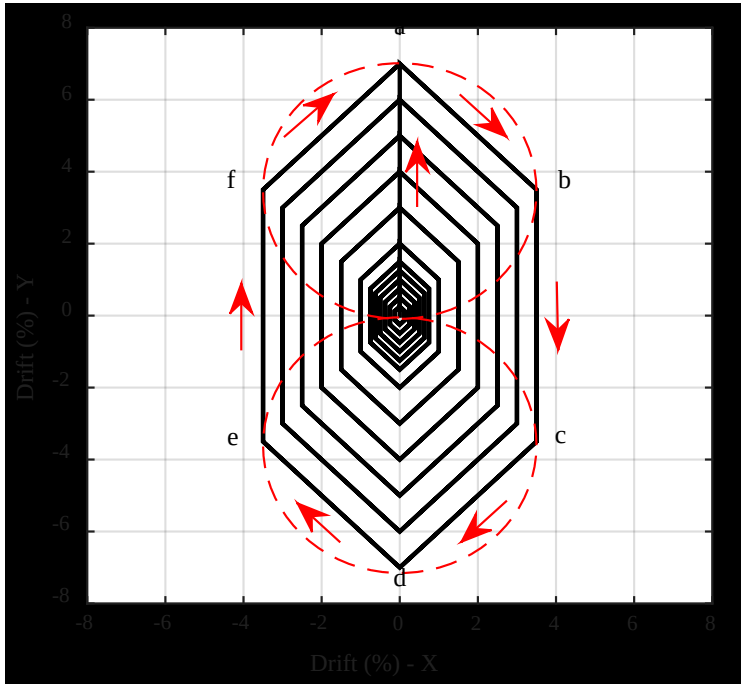
New/Improved Retrofit Options (5/6 completed)

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*
5. *Use Christchurch Data to Identify Unsuccessful Retrofitting Techniques and Investigate Possible Improvements*
6. *In-situ tests of URM houses to start in Dec'15. Minimum of 3 houses and 3 walls / house plus chimneys.*

Recent Progress

2. Moment Frame Structures with In-situ RC Columns

- Obtaining modelling parameters from Quasi-Static Cyclic Test



Hexagonal orbital pattern for bidirectional lateral deformation reversals (FEMA 461, implemented by research fellow, Javad Hashemi)

Recent Progress

3. Structures with RC Walls
   - Collapse Behaviour:
   - (i) Out-of plane buckling (*left*)
   - (ii) Local bar buckling (*right*)

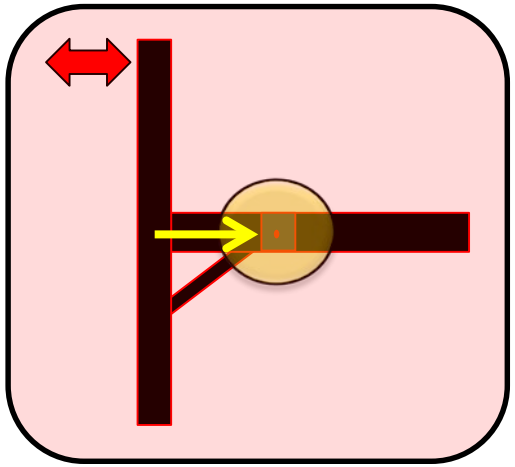
Tension-compression tests by PhD student, Scott Menegon

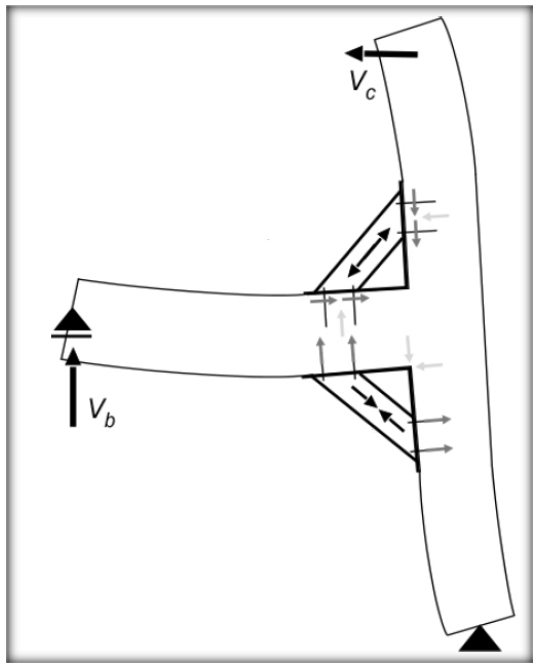
Recent Progress

5. Seismic Retrofit Techniques

5.2 Metallic Haunch Element

- Less invasive with post-installed anchoring system
- Load redistribution & relocating plastic hinge





Prepared by PhD student, Alireza Zabihi

FRP STRENGTHENED BRICK MASONRY WALLS AT FAILURE

(10 – 20 TIMES STRONGER THAN UNREINFORCED)

(a) Wall 5

(b) Wall 6

(c) Wall 8

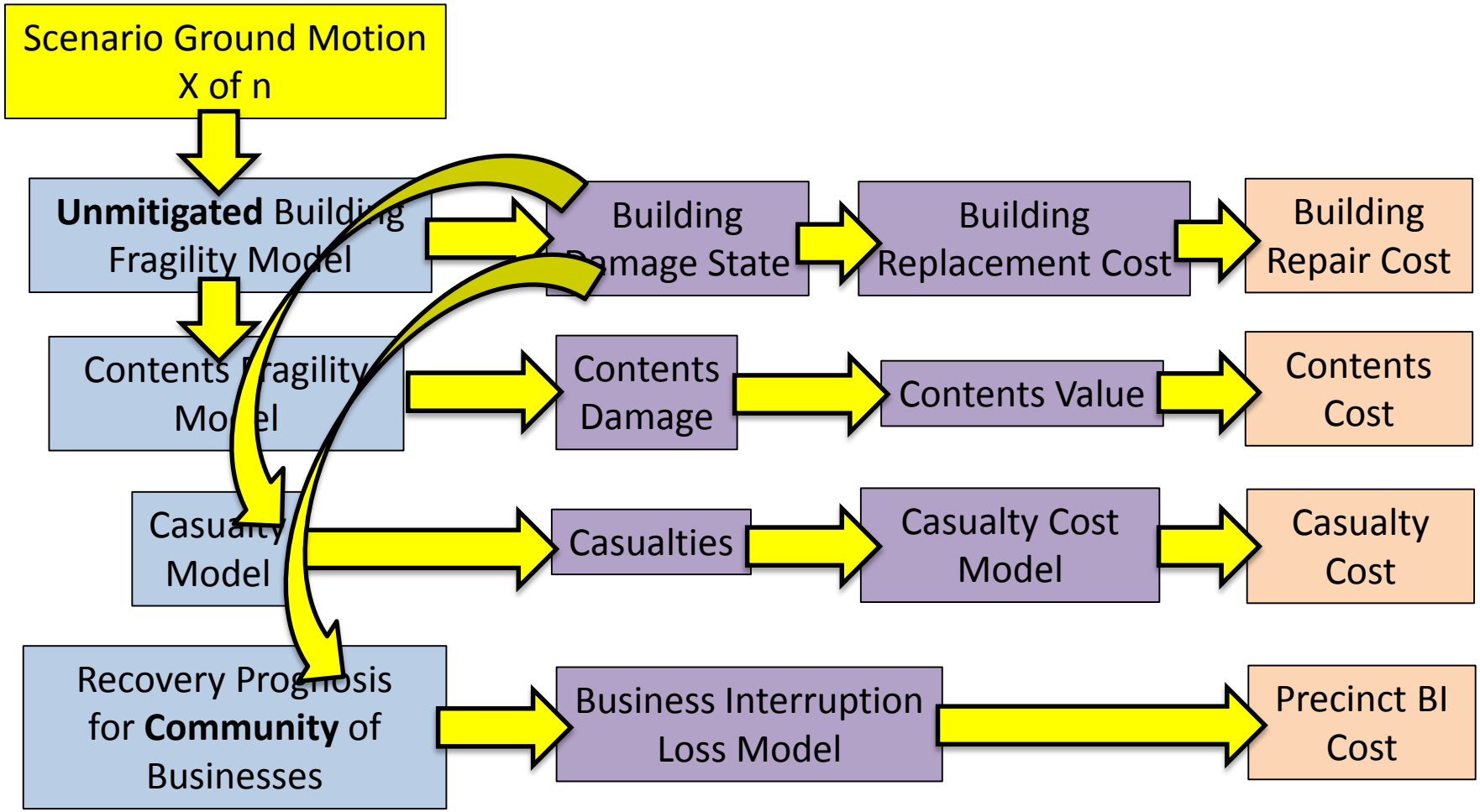
Damage & Economic Loss Modelling

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*

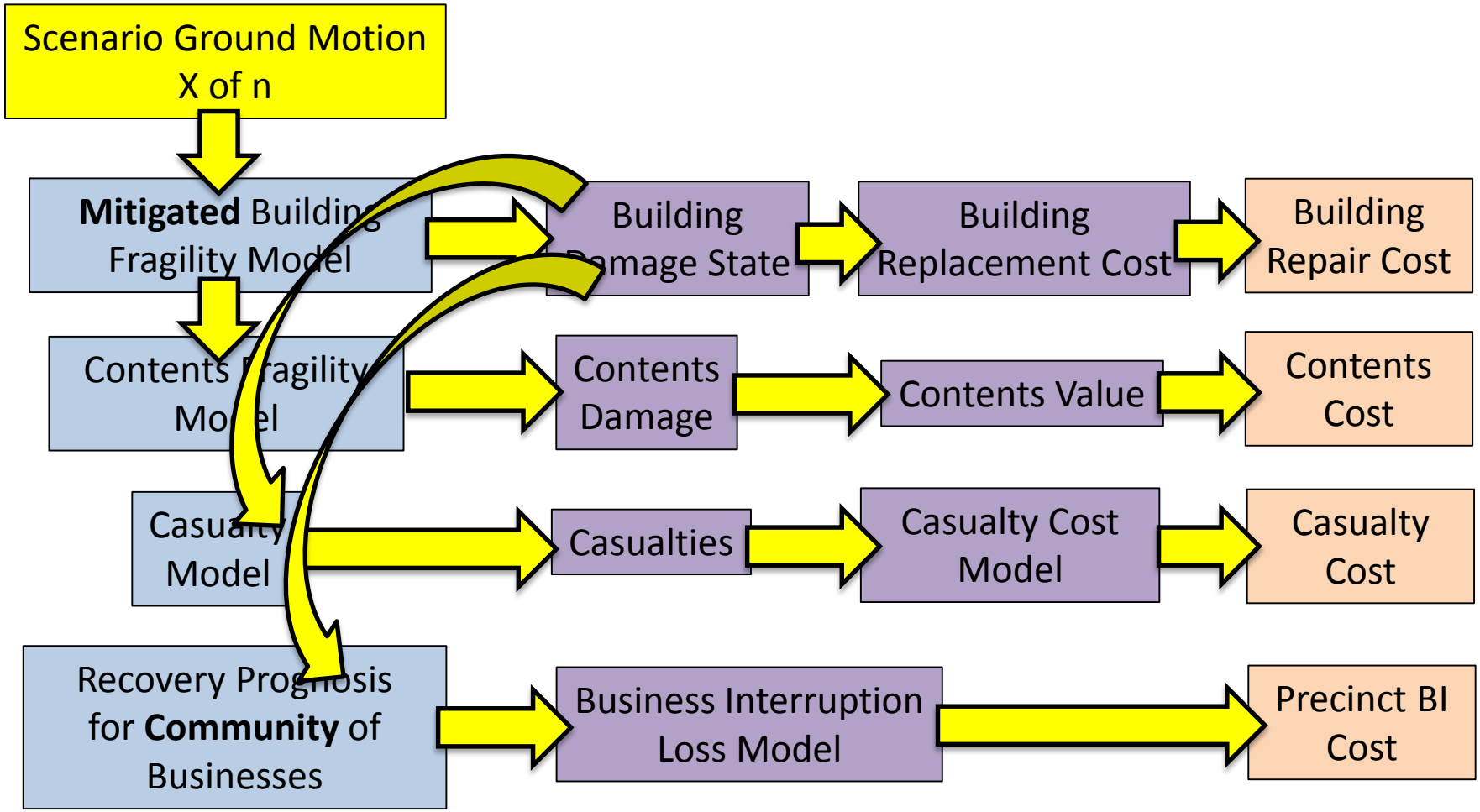
1, 2 ‘done’; 3 in progress; 4 ???

Precinct Modelling Logic – Unmitigated Baseline



Total Unmitigated Precinct Loss for Scenario X =

Precinct Modelling Logic – Mitigated Shift



Total Unmitigated 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 need better 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.