bushfire&natural HAZARDSCRC

BNHCRC: RESEARCH ADVISORY FORUM

3 & 4 DEC. 2014

PROJECT B8: ENHANCING RESILIENCE OF CRITICAL ROAD STRUCTURES: BRIDGES, CULVERTS AND FLOOD WAYS UNDER NATURAL HAZARDS

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An Australian Government Initiative

CRC AUSTRALIA

OUTLINE

1) Project overview
2) Progress to date
3) Vulnerability assessment methodology
4) An example of use of damage index
5) End user engagement
6) Way forward
7) Questions / Comments

PROJECT OVERVIEW

RESEARCHERS & END USERS

Enhancing resilience of critical road structures: bridges, culverts and flood ways under natural hazards

4 strands

Structures:

- BRIDGES
- CULVERTS
- FLOOD-WAYS

Hazards:

- EARTHQUAKE
- FLOOD
- BUSHFIRE
- CLIMATE CHANGE

PEOPLE

1) Prof. Sujeeva Setunge (RMIT)
2) Prof. Chun-Qing Li (RMIT)
3) Prof. Darryn McEvoy (RMIT)
4) A/Prof. Kevin Zhang (RMIT)
5) Prof. Priyan Mendis (Melb. Univ.)
6) Dr. Tuan Ngo (Melb. Univ.)
7) Prof. Karu Karunasena (USQ)
8) Dr. Weena Lokuge (USQ)
9) Prof. Dilanthi Amaratunge (Huddersfield , UK)

- Dr. Ross Prichard (TMR Qld)
- Mr. Nigel Powers (VicRoads)
- Prof. Wije Ariyaratne (RMS NSW)
- Dr. Neil Head, Attorney General Dept.
- Ms. Leesa Carson, Geoscience Aust.
- Mr. Myles Fairbairn, Locker Valley Regional Council

Three HDR students funded by RMIT

- Farook Kalendhar
- Albert (Yue) Zhang
- Amila Gunasekara (commencing in 2015)

PROJECT OBJECTIVES

1) Stage 1: Vulnerability Modelling

Analysis of case studies of failure – Lockyer Valley and Great Ocean Road

a) Input exposure parameters for multi hazard analysis
b) Critical failure mechanisms and modes
c) Community Impact of failure of road structures
d) Analysis of Australian design standards, identify gaps
e) Vulnerability modelling of road network for failure of road structures

1) Stage 2: Prototype tool for vulnerability of road structures,

Develop a GIS tool to map vulnerability

a) Calibrate the vulnerability models with two other case study areas
b) Identify strengthening methods
c) Deliver a methodology and a tool for optimised strengthening of structures

PROGRESS TO DATE

PROGRESS TO DATE

End-user engagement

- End-user meetings with VicRoads to discuss requirements and methodology framework - condition data provided for the full network;
- End-user workshop at USQ with Lockyer Valley Regional Council (LVRC) for brainstorming and methodology discussion as well as data collection and planning 25 July 2014
- Meeting with engineering consultants of LVRC 29 Nov. 2014
- Workshop at Department of Transport and Main Roads Queensland (QTMR) end-user workshop to discuss and refine the methodology 30 Nov. 2014

PROGRESS TO DATE contd.

Analysis & development

- A draft **vulnerability assessment framework** has been developed which is common to all four strands of the project;
- Engineering analysis on modelling **Tenthill Creek bridge**;
- **Damage index** methodology has been developed and a case study analysis carried out for floodways. A journal paper prepared and submitted for CRC review;

A few site visits, workshops and brainstorming sessions

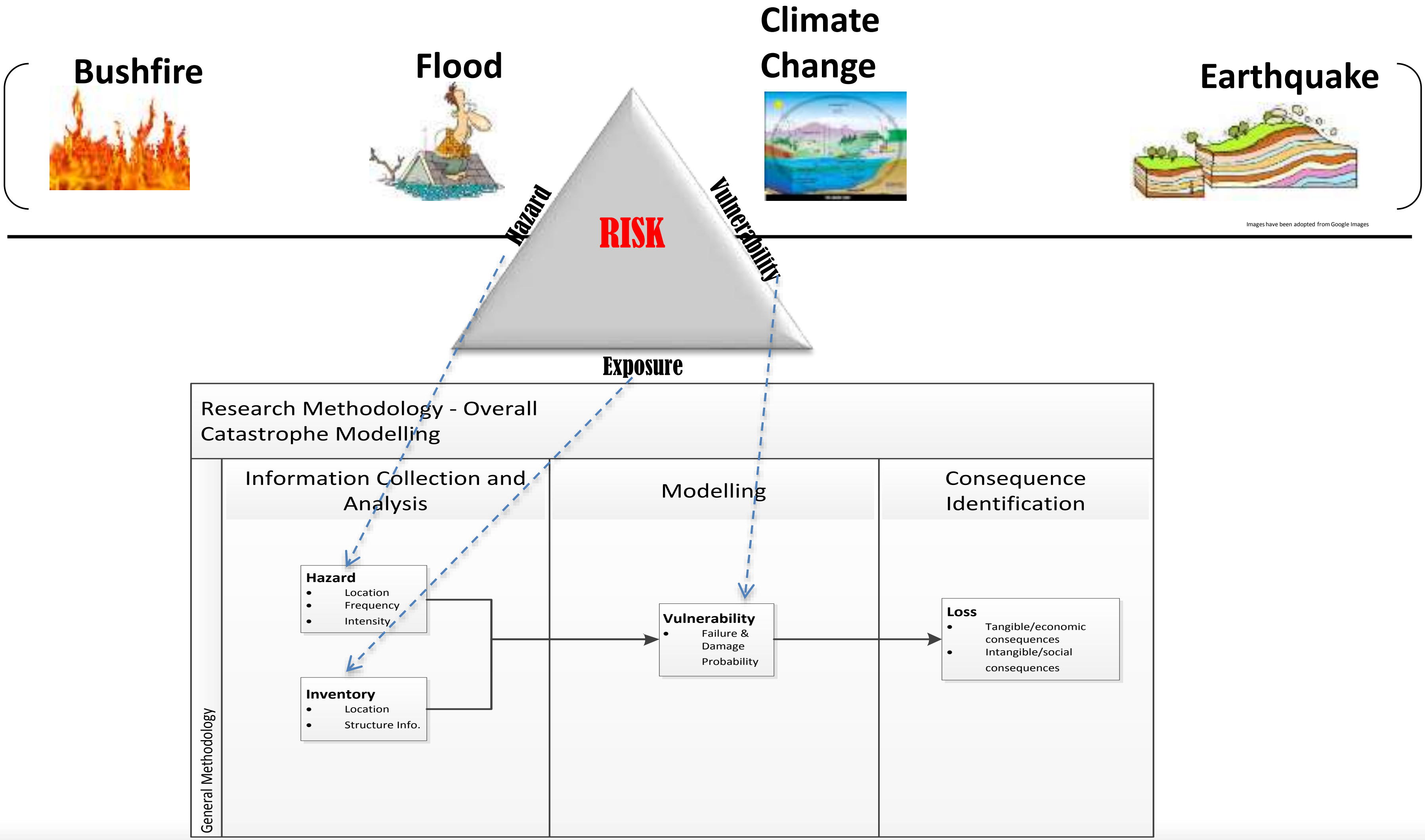
END USER THOUGHTS IN A NUTSHELL

- VicRoads prefers mitigation methods other than strengthening
  - Eg. Remove vegetation to reduce bush fire damage
- LVRC requires a method to optimise investment so that critical structures can be reconstructed resist the next flood – how do you identify critical structures ?
- QTMR
  - Understand effect of flood damage
  - Scour/approach failure not fully covered by Austroads
  - Simple measures such as locating storm water lines down stream side of the bridge – where should we include these types of provisions ?
  - Consequences and community impact should be the starting point of the investigations
  - Collect scattered data so that informed decisions can be made during reconstruction

METHODOLOGY FOR VULNERABILITY ASSESSMENT OF ROAD STRUCTURES

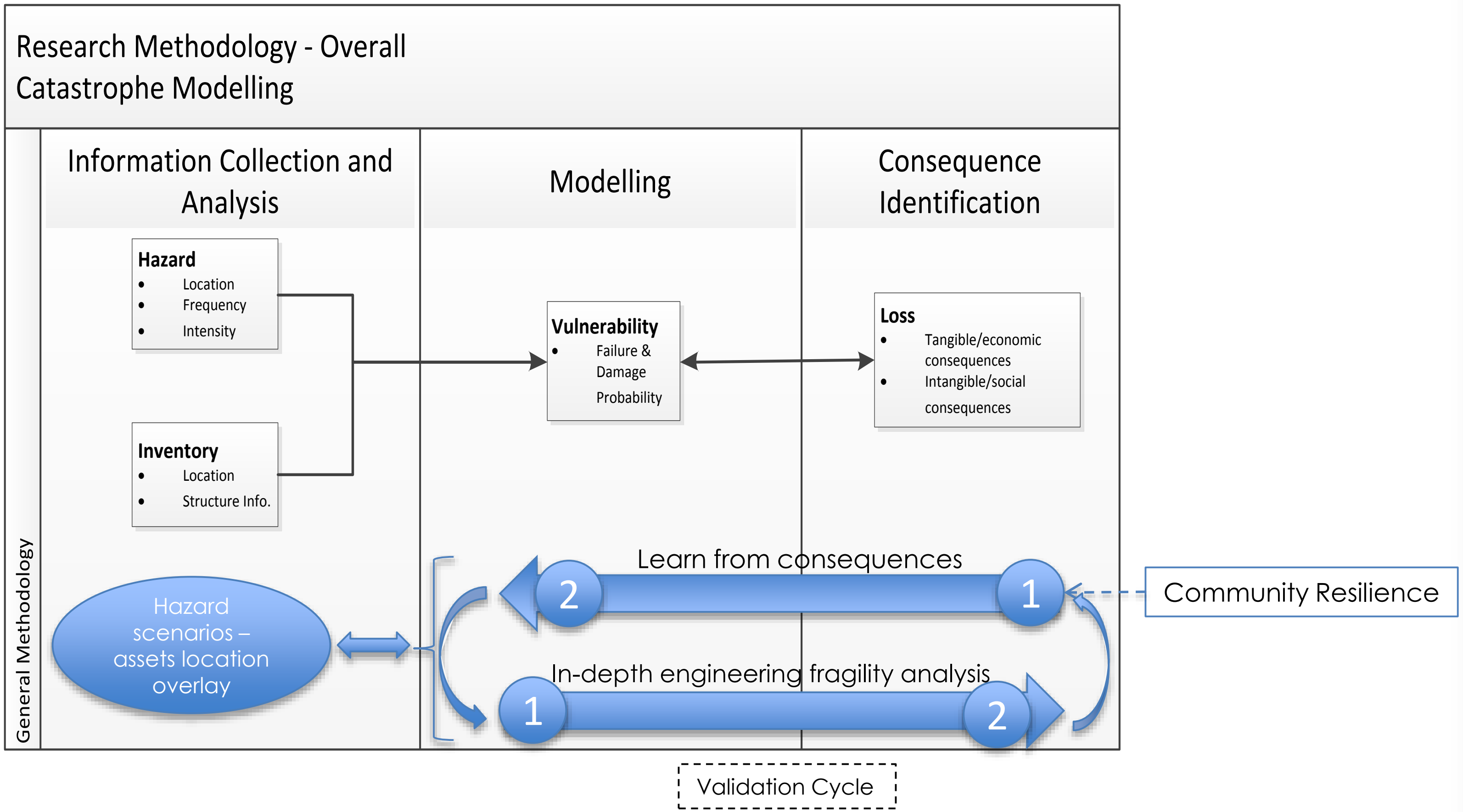
RESEARCH PROGRAM – STAGE 1 - METHODOLOGY

Assessment of Road Infrastructure



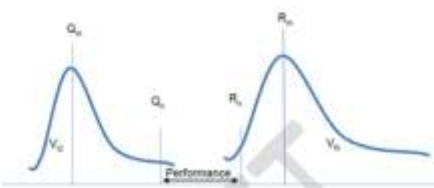
RESEARCH PROGRAM - METHODOLOGY REFINED

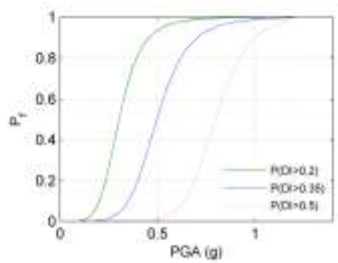
Assessment of Road Infrastructure

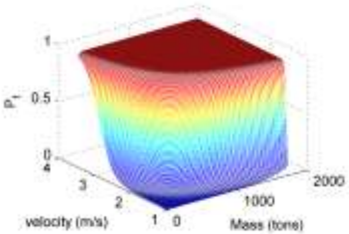


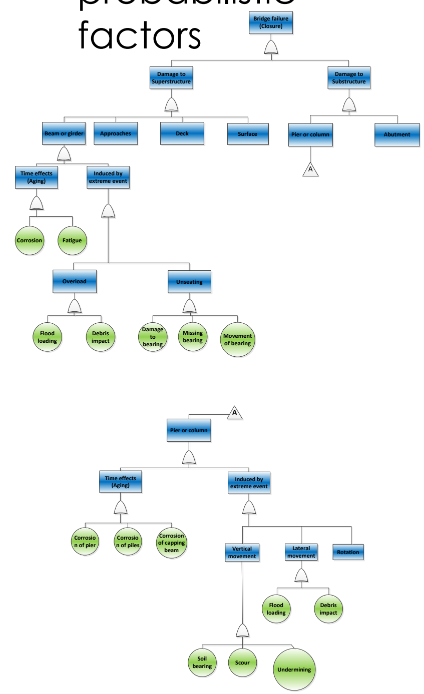
VULNERABILITY ASSESSMENT – LEVELS OF DETAIL

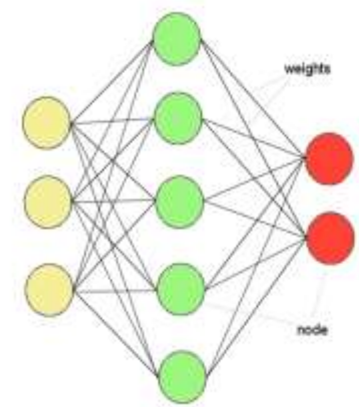
Structural reliability	Damage Index	Fault Tree	ANN
• Design action and resistance probabilities due to extreme loading • Reliability index • Risk quantification $\beta = \ln[(\frac{R_m}{Q_m})\sqrt{\frac{C_Q}{C_R}}] / \sqrt{\ln(C_R \cdot C_Q)}$	$D_{fi} = \left(\frac{\varphi_{max}}{\phi_u}\right)^{\alpha}$ $\text{Damage index} = \frac{\text{Cost for repair}}{\text{Cost of replacement}}$	• Risk identification • Failure mechanisms & contributing probabilistic factors	Fundamental components of biological neural nets: • Neurones (nodes) • Synapses (Weights) • Input layer • Hidden layer • Output layer $O = N_3[N_2[N_1[I]]]$











RESEARCHERS INITIAL DATA WISH LIST

Basic Information on structures (bridges, flood-ways & culverts)

- Structure name
- Structure location (Road, Chainages, Elevations etc)
- Type of structure
- Structure drawing
- Construction material
- Age of structure
- Repair/Replacement/Construction Cost (with cost distribution if available)

Geometric & Safety

- Length: More than 300m / Less than 300m
- Located on a horizontal curve? Yes/No
- Located on a vertical curve? Yes/No

Environmental Aspects

- Fish Migration is a concern? YES/NO
- Sufficient provision provided: YES/NO
- Surrounding terrain and vegetation/fuel

Traffic Information

- Road Category
- Design Traffic Flow

Hydraulic Design Aspects

- Any floodplain study available such as:
- Flow over the Road (Q) =
    - C_f (Coefficient of discharge 'free' flow)
    - C_s (Coefficient of discharge flow with submergence)
  - Design upstream velocity (V) =
  - Level difference between the floodway crown and the upstream water surface (h)

Other Aspects

- Soil profiles of the case study regions
- Time of Submergence
  - During a Major Flood (including average recurrence interval)–
  - Average Annual Time Of Submergence (AATOS) –
- Time of Closure
  - During a Major Flood (including average recurrence interval)–
  - Average Annual Time Of Closure (AATOC) –

Failure Mechanisms

- Identified failure mechanisms
- General Observations
- Any available Analysis Results (such as debris loads, economic impact …)

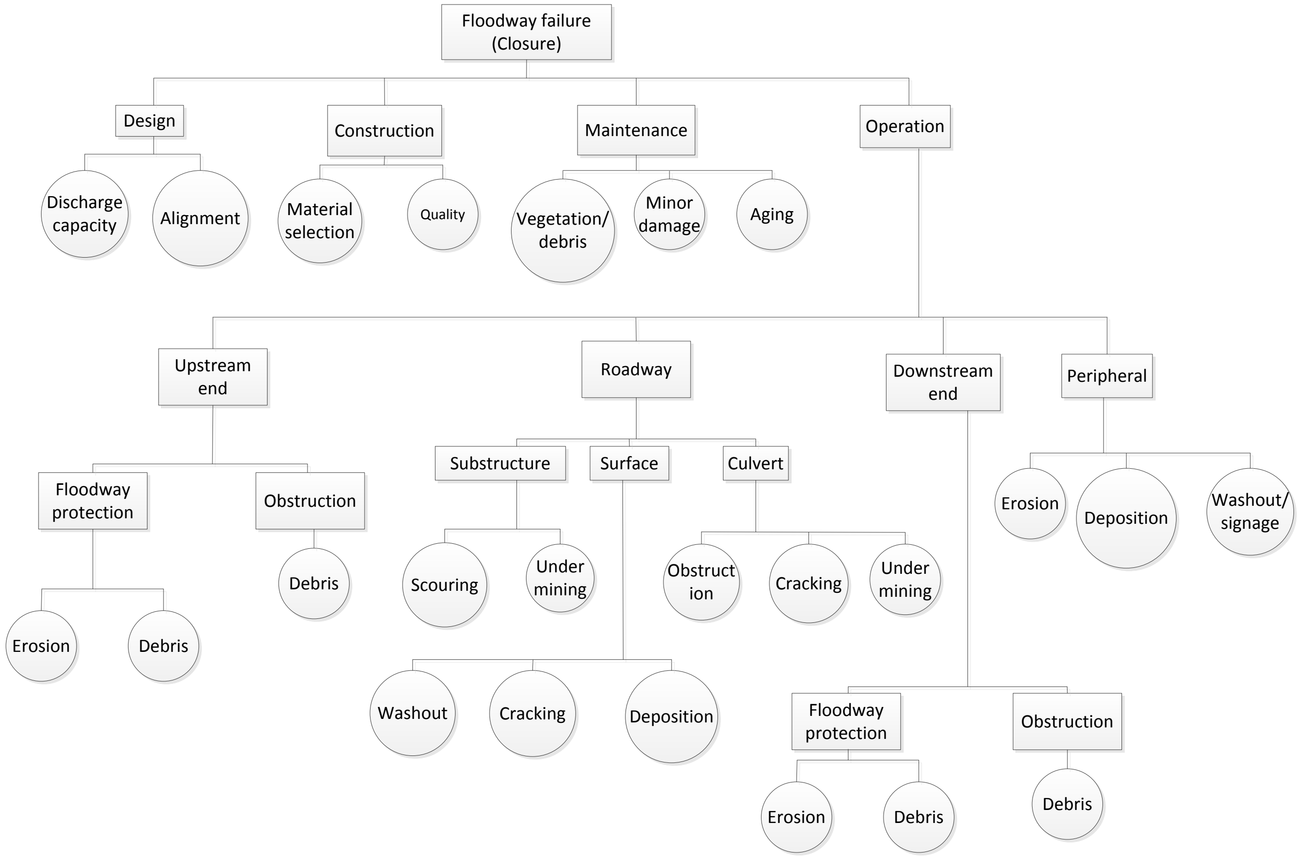
Hazard information

- Historical hazard frequency, intensity & damage scale
- Any other references used

Social aspects

- GIS layers for the area
- Road usage data (before, during and after the flooding)
- Identify the flooding events - timeline for the area
- Timeline for the bridge (and other road) repair
- Community data for people who use the roads - socio-economic
- Nearest schools, hospitals, GPS, shops, fuel stations, evacuation centres etc
- Any information on existing resilience work carried out by council or govt. In the community
- Before and after the flood event population figures
- Identify local action groups, other groups

AN EXAMPLE – Flood-way Fault Tree



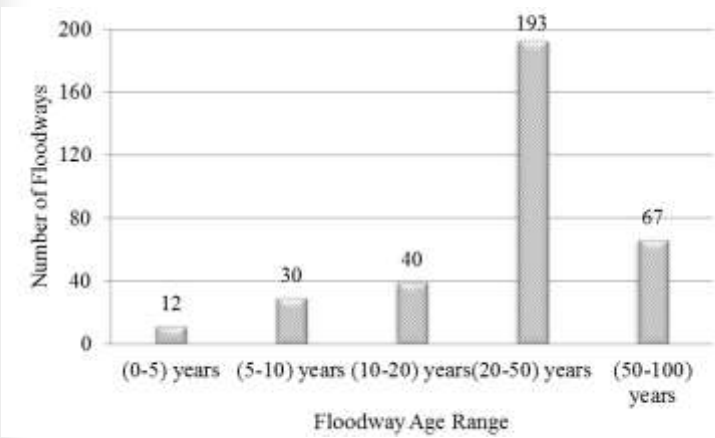
AN EXAMPLE – Damage Index

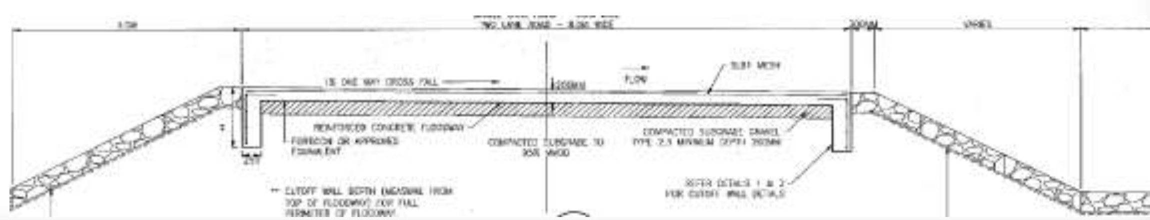
$$Damage\ Index\ (DI) = \frac{Repair\ \ Cost}{Estimated\ \ Repl\,acement\ \ Cost}$$

$$Contributing\ Factor\ for\ item\ 'i' = \frac{Repair\ Cost\ for\ item\ 'i'}{Estimated\ replacement\ cost}$$

$$DI = \sum Contributing\ Factors\ for\ items\ 'i'$$

CASE STUDY – Lockyer Valley





AN EXAMPLE – Continued

Tenthill Creek and Left Hand Branch rd

Common failure mechanisms

Washout

Cracking

Undermining

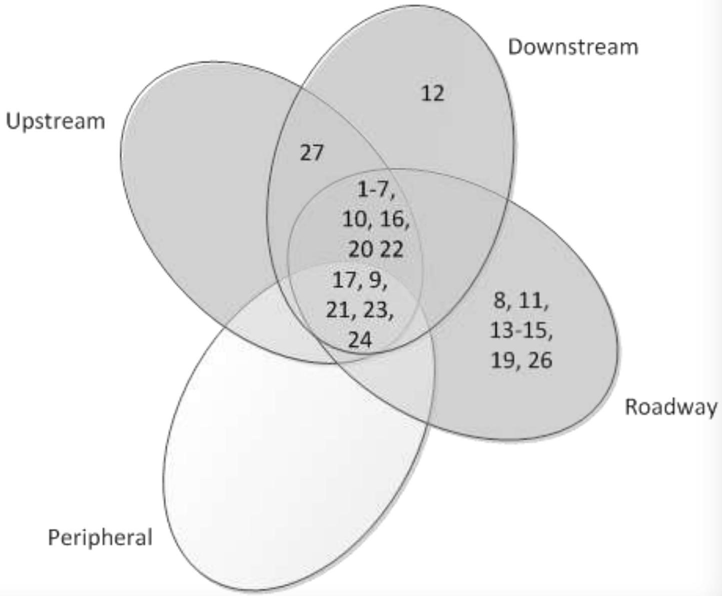
Damage to rock protection

Culvert blocking

Scouring

AN EXAMPLE - Failure Distribution in the Network

Damage Zone	Failure Mode	Floodway No
All four zones	Obstruction - debris	9,17,24,21,23
	Guide/post markers	21,23
Upstream, Downstream and Roadway Zones	Washout	2,3-6,10,20,22
	Scouring	1
	Undermining	1,4,7,16
	Damage to rock protection	4
	Cracking	4, 16
	Damage to apron	7
Upstream and Downstream zones	Damage to apron	27
	Scouring	27
Downstream Zone	Scouring	12
	Damage to rock protection	12
	Damage to apron	12
Roadway Zone	Cracking	8
	Surface Erosion	11
	Culvert – washout	13,15
	Culvert – Damaged	14
	Culvert - Blocked	19,26

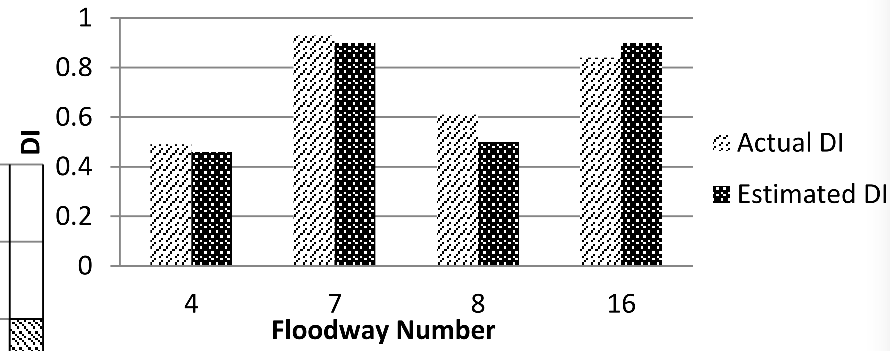


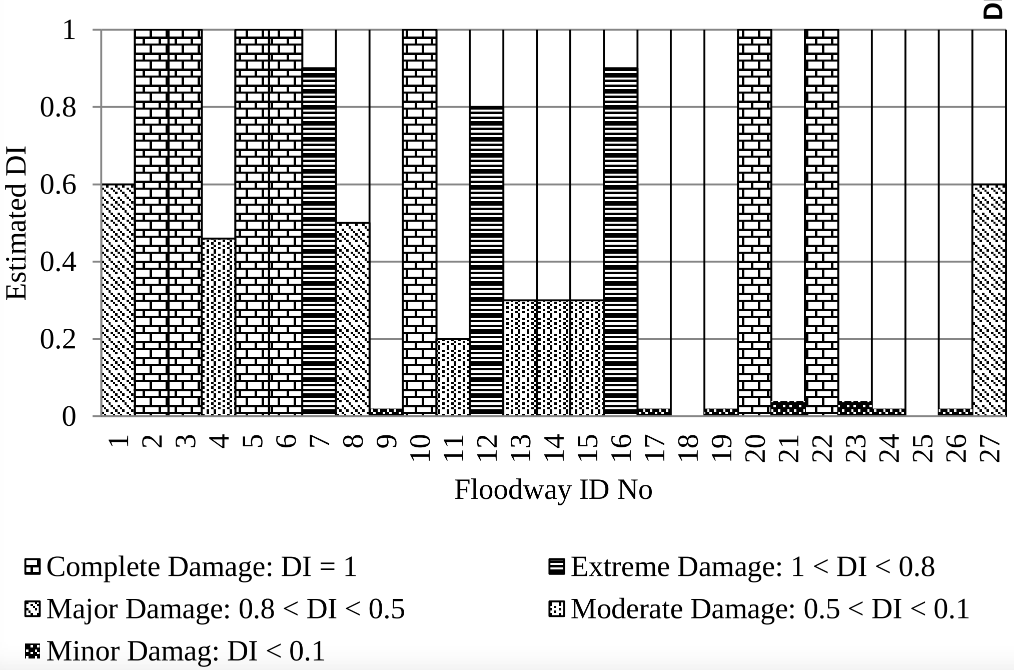
AN EXAMPLE – Continued - Contributing factors for damage

Item No	Item	Maximum fractional Cost
A	Construction of temporary road	0.05
B	Partial / fully demolishing and removing existing culverts, pipes, and concrete structures	0.10
C	Repair / Reconstruction of concrete floodway including culverts if any	0.25
D	Repair / Reconstruction of apron	0.50
E	Placing geotextile fabric in conjunction with rock fill	0.01
F	Construction of rock protection	0.05
G	Replacing sign posts and standard road signs	0.02
H	Clearing debris material	0.02

AN EXAMPLE - Estimated Damage Indices

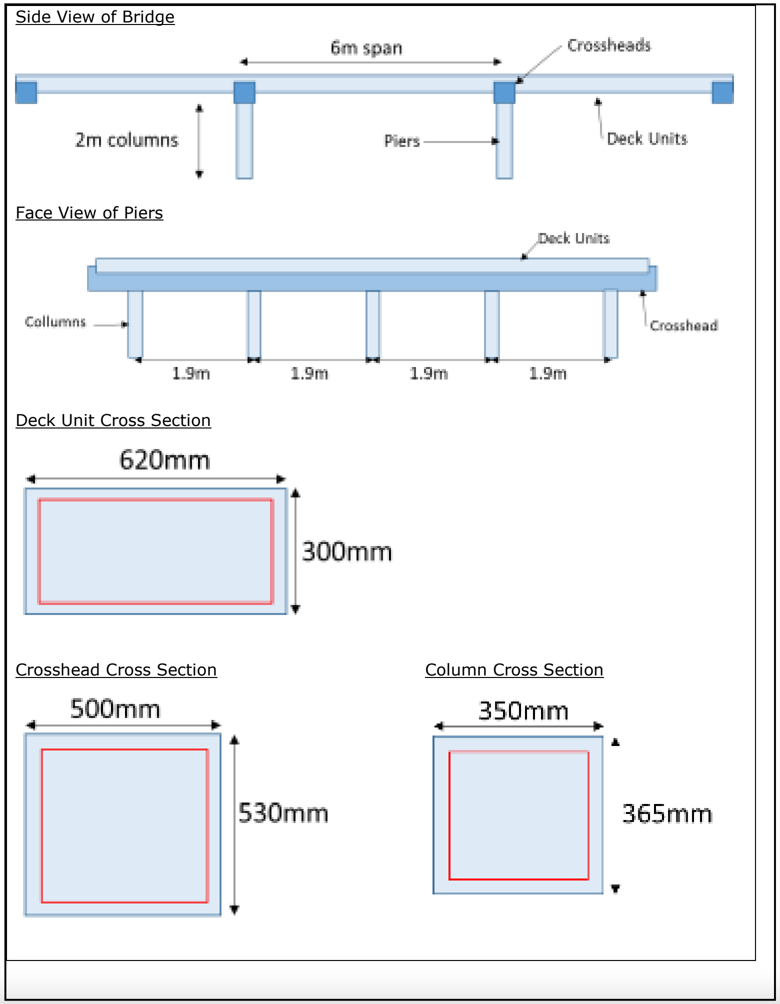
ID No	Description of damage	Repair cost ($)	Estimated Replacement cost ($)	DI
4	Damage to rock protection, undermined and minor cracking	91,592	185,776	0.49
7	Seriously undermined and apron has been damaged	91,535	98,903	0.93
8	Cracking of floodway	67,547	109,965	0.61
16	seriously undermined and cracked	113,301	134,485	0.84





ANOTHER EXAMPLE - Fire impact on case study bridge in Victoria

Bloomfield Rd over Hazel Creek, Warragul



Fire impact on case study bridge in Victoria

Variable exposure time

Depth of T500		K_c (at depth from exposed surface)			
time	mm	50mm	100mm	150mm	200mm
30	10	0.88	1	1	1
60	21	0.64	0.975	1	1
90	29	0.43	0.92	1	1
120	36	0.3	0.825	0.99	1
180	49	0.15	0.64	0.95	1

Temperature at 30mm (reinforcement)			
time	T(°C)	r	$r_{residual}$
30	230	1	1
60	395	0.649	1
90	495	0.436	1
120	570	0.277	0.93
180	680	0.043	0.82

$$(EI)_z = [k_c(\theta_M)]^2 \cdot E_c \cdot I_z$$

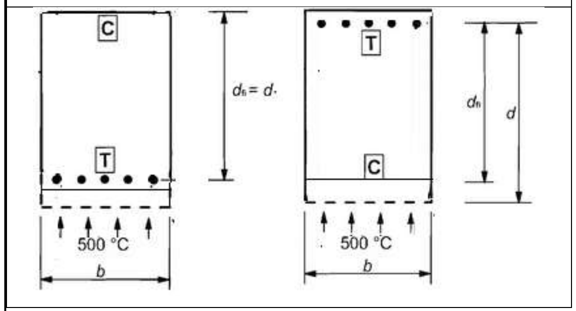
where

$k_c(\theta_M)$ is a reduction coefficient for concrete at point M (see B.2)

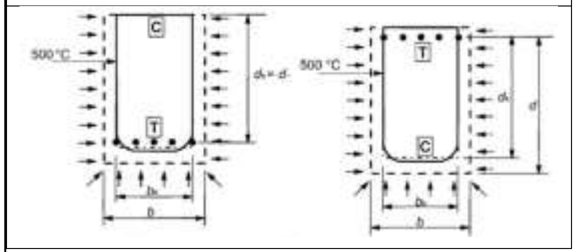
E_c is the elastic modulus of the concrete at normal temperature

I_z is the 2nd moment of area of the reduced section

Reduced cross-section of reinforced concrete under 1 dimensional heat penetration in slabs.



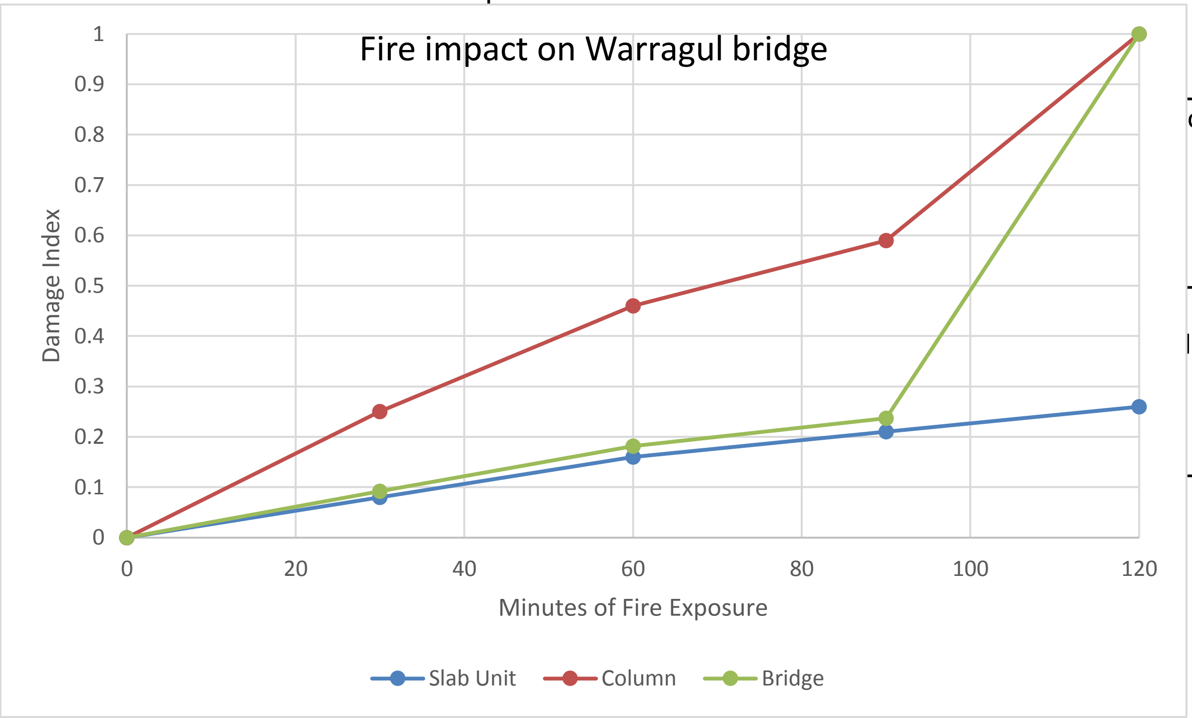
Reduced cross-section of reinforced concrete under 3 sided heat penetration in beams.



		Mid span			Above Pier			
			Mu factor			Mu factor		
	B (mm)	d(mm)	During Fire	After Fire	d(mm)	During and After Fire	$K_{c,mean}$	stiffness factor
T(30)	610	270	1.000	1.000	260	0.963	0.951	0.803
T(60)	599	270	0.650	1.000	249	0.922	0.926	0.667
T(90)	591	270	0.438	1.000	241	0.892	0.910	0.581
T(120)	584	270	0.278	0.930	234	0.866	0.897	0.516
T(180)	571	270	0.043	0.821	221	0.818	0.884	0.422

Fire impact on case study bridge in Victoria – Initial Findings

Exposure Time	Deck Units	Columns
30 minutes	Stiffness has dropped by close to 20%. No risk of failure. Small amount of extra damage from deflection likely.	Moment capacity has dropped by 5%, compression capacity has dropped by 13%, and stiffness has dropped by 60%. No risk of failure.
60 minutes	Sagging moment capacity has dropped by 35%, and stiffness by 33%. Failure unlikely. Extra damage from de	Moment capacity has dropped by 29%, compression capacity has dropped by 29%, and stiffness has dropped by 75%.
90 minutes	Sagging moment capa by 42%. Failure unlikely. Extra damage from de	city
120 minutes	Sagging moment capa by 48%. Flexural Failure possib Extra damage from de	l by



WAY FORWARD

WAY FORWARD (NEXT 6 MONTHS)

- Engineering analysis continued
- Ongoing data and consequence extraction; estimation and validation, starting from impact
- Report on community impact
- Major workshop with end-users on community resilience
-
- Report on failure mechanisms for bridges
- Workshops and discussions with end-users to fine-tune the methodology

QUESTIONS / COMMENTS / FEEDBACK