bushfire&natural HAZARDSCRC

ENHANCING RESILIENCE OF CRITICAL ROAD STRUCTURES – RESEARCH ADVISORY FORUM

RMIT UNIVERSITY 25TH & 26TH OCTOBER 2017

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

RMIT UNIVERSITY

THE UNIVERSITY OF MELBOURNE

UNIVERSITY OF SOUTHERN QUEENSLAND

RESEARCHERS & END USERS

Australian Government
Geoscience Australia

vic roads

RMIT UNIVERSITY

Roads & Maritime

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

MAV
MUNICIPAL ASSOCIATION OF VICTORIA

bushfire&natural HAZARDSCRC

THE UNIVERSITY OF MELBOURNE

Australian Government
Attorney-General's Department

Structures:

- BRIDGES
- CULVERTS
- FLOOD-WAYS

Hazards:

- EARTHQUAKE
- FLOOD
- BUSHFIRE
- CLIMATE CHANGE

UNIVERSITY OF SOUTHERN QUEENSLAND

Queensland Government
Department of Transport and Main Roads

Lockyer Valley REGIONAL COUNCIL

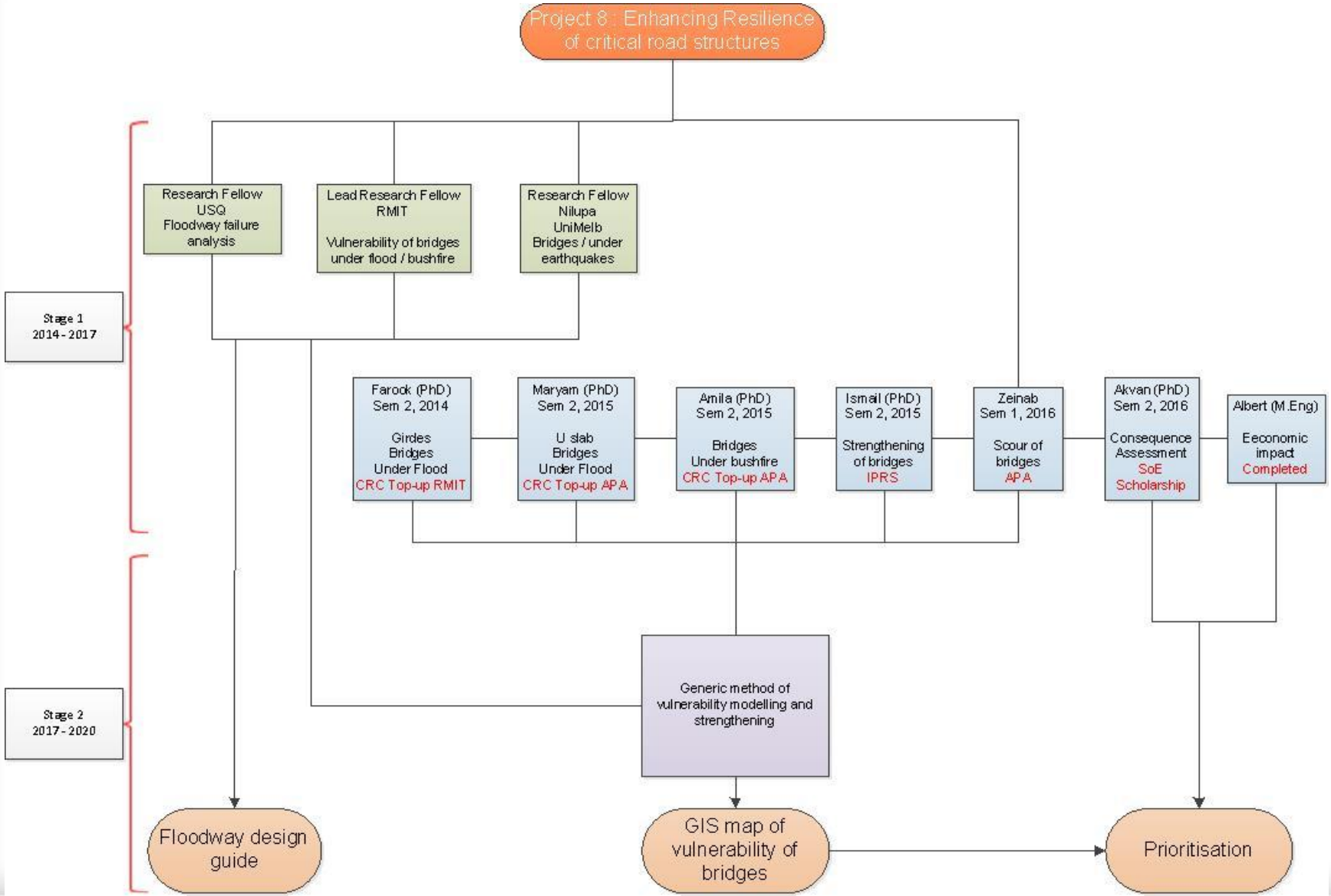
PROJECT OVERVIEW

- Stage 1 Jan.2014-June 2017
  - **Vulnerability modelling of critical road structures – Bridges and Foodways under flood, bush fire and earthquakes, develop methodology and validation**
- Stage 2 July 2017-June 2020
  - **Simplify the analysis methods for network wide application**
  - **Develop ranking of road structures for the state of Victoria/Qld for the three hazards**
  - **Develop a design guideline for resilient flood-ways**

PEOPLE

	RMIT, UniMelb, USQ & Huddersfield	End-Users	Research Students
1	Prof. Sujeeva Setunge (RMIT)	Mr. Bob Barrett (TMR Qld) Mr. George Llic (TMR Qld)	Mr. Farook Kalendhar (RMIT scholarship)
2	Prof. Chun-Qing Li (RMIT)	Mr. Myles Fairbairn (LVRC) Mr. Quentin Underwoood (LVRC) Mr. Tony McDonald (LVRC)	Mr. Albert (Yue) Zhang
3	Prof. Darryn McEvoy (RMIT)	Dr. Yew Chin Koay (VicRoads)	Ms. Maryam Nasim (APA)
4	A/Prof. Kevin Zhang (RMIT)	Mr. Henry Luczak (VicRoads)	Mr. Amila Gunasekara (APA)
5	Prof. Priyan Mendis (UniMelb)	Prof. Wije Ariyaratne (RMS NSW)	Mr. Ismail Queshta (IPRS)
6	Dr. Tuan Ngo (UniMelb) Dr. Lihai Zhang (Unimelb)	Dr. Neil Head (Attorney General Dept.)	Ms. Zeinab Yazdanfar (APA)
7	Prof. Karu Karunasena (USQ)	Ms. Leesa Carson (Geoscience Aust.)	Mr. Akvan Gajanayake (RMIT scholarship)
8	Dr. Weena Lokuge (USQ)	Mr. Ralph Smith (DFES WA)	
9	Prof. Dilanthi Amaratunga (Huddersfield , UK)		
10	Dr. Hessam Mohseni (RMIT)		
11	Dr. Buddhi Wahalathantri (USQ)		
12	Dr. Nilupa Herath (UniMelb)		
13	Dr. Jane Mullet (RMIT)		

RESEARCH TEAM



WE ARE NOT ALONE

HAZUS MH
EARTHQUAKE • WIND • FLOOD

FEMA

Table 7.2 Highway Single-span Bridge Damage Relationship

Flood Return Period	Scour Potential[1]/Probability of Failure (percent)				
	1	2	3	4-8	9
100-year	5	2	1	0	N/A
500-year (2x 100-year probability)	10	4	2	0	N/A
1000-year (1.5x 500-year probability)	15	6	3	0	N/A

The Scour Potential is a field in the Hazus Bridge database and is from the FHWA inventory of bridges

Table 7.3 Highway Continuous-Span Bridge Damage Relationship

Flood Return Period	Scour Potential[1]/Probability of Failure (percent)				
	1	2	3	4-8	9
100-year	1.25	0.5	0.25	0	N/A
500-year (2x 100-year probability)	2.5	1	0.5	0	N/A
1000-year (1.5x 500-year probability)	3.75	1.5	0.75	0	N/A

[1] *The Scour Potential is a field in the Hazus Bridge database and is from the FHWA inventory of bridges*

In the future, it may be possible to develop damage relationships for different bridge span materials (concrete, steel, wood), but no data exists, and the focus is on the bridge foundation vulnerability rather than the span.

9.4 Damage Functions

The Flood Model default data includes over 700 depth-damage functions that relate water depth to structure and content percent damage. The Damage Functions includes Buildings, Essential Facilities, Transportation Systems, Utility Systems, Agricultural Products, and Vehicles. All of

Table D.12 Highway Bridges
Table
flHighwayBridge

Name	Description	Format	Default Value
HighwayBridgeId	Highway bridge unique id	char(8)	not null
Elevation	Bridge elevation above surface of normal flow (not used)	float	null

Table D.13 Railway Bridges
Table
flRailwayBridge

Name	Description	Format	Default Value
RailwayBridgeId	Railway bridge unique id	char(8)	not null
Elevation	Bridge elevation above surface of normal flow (not used)	float	null

Table D.29 Bridge Damage Functions for Highway, Railway, and Light Rail
Table
flBridgeDmgFn

Name	Description	Format	Default Value
BridgeDmgFnId	Bridge damage function unique id	numeric	not null
Occupancy	Bridge specific occupancy	char(7)	null
Source	Damage function source	char(16)	null
Description	Damage function description	varchar(50)	null
RP0	Percent damage for return period 0-years	real	null
RP25	Percent damage for return period 25-years	real	null
RP50	Percent damage for return period 50-years	real	null
RP75	Percent damage for return period 75-years	real	null
RP100	Percent damage for return period 100-years	real	null
RP125	Percent damage for return period 125-years	real	null
RP150	Percent damage for return period 150-years	real	null
RP175	Percent damage for return period 175-years	real	null
RP200	Percent damage for return period 200-years	real	null
RP225	Percent damage for return period 225-years	real	null
RP250	Percent damage for return period 250-years	real	null

OUTCOMES TO DATE

- The methodology for evaluating vulnerability based on structural capacity established

- Case studies of failure of bridges under natural hazards completed –methodology of analysis demonstrated
  - Flood – Lockyer Valley bridge case studies
  - Bushfire – Effect of fire on concrete bridges, Steel bridges
  - Earthquakes – Lockyer Valley girder bridge under earthquake

- Methodology for establishing damage curves based on cost of recovery developed, with a floodway case study

- Vulnerability of floodways and resilient design examined

- Community resilience study conducted – researchers spent a week in Lockyer valley interviewing community

- A method to quantify the economic impact of failure of road structures established

DISSEMINATION

REPORTS

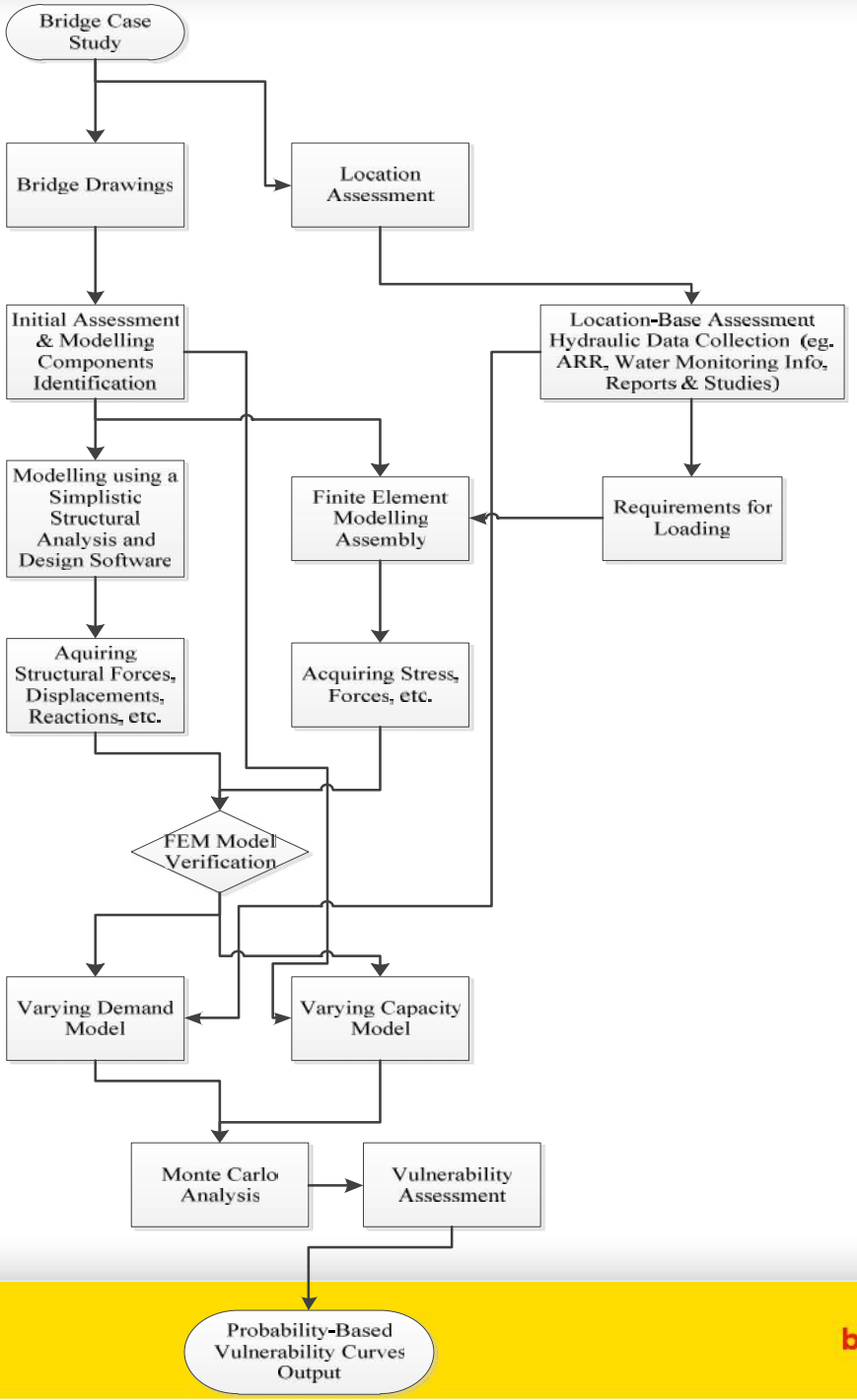
- Report 1: Failure of road structures under natural hazards
- Report 2: Community resilience to flooding and road network disruption
- Report 3: Failure mechanisms of bridge structures under natural hazards
- Report 4: Analysis of design standards and applied loads on road structures under extreme events
- Report 5: Vulnerability Modelling

JOURNALS AND CONFERENCES

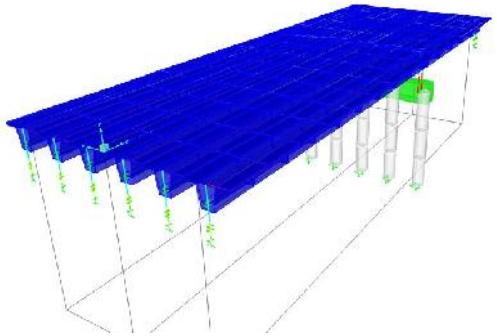
- 9+ Journal papers
- 12+ refereed conference papers

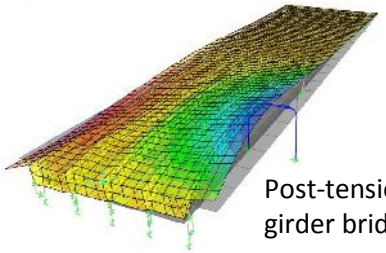
RESEARCH PROCESS

Vulnerability Assessment

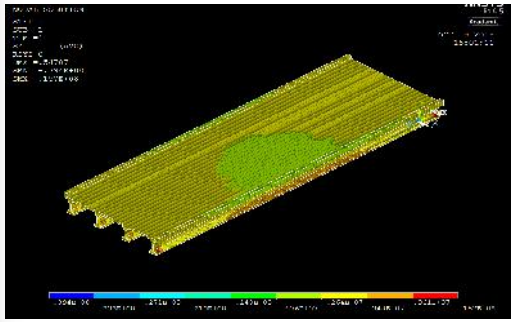


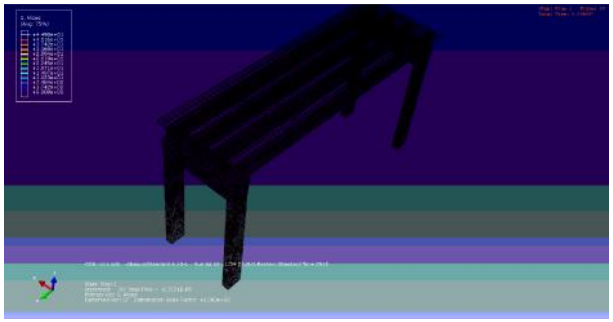
DAMAGE CURVES - BRIDGES UNDER FLOOD, BUSHFIRE & EARTHQUAKE

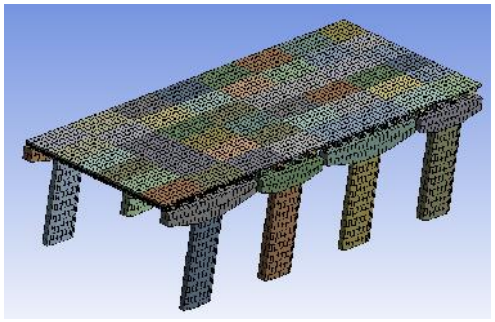


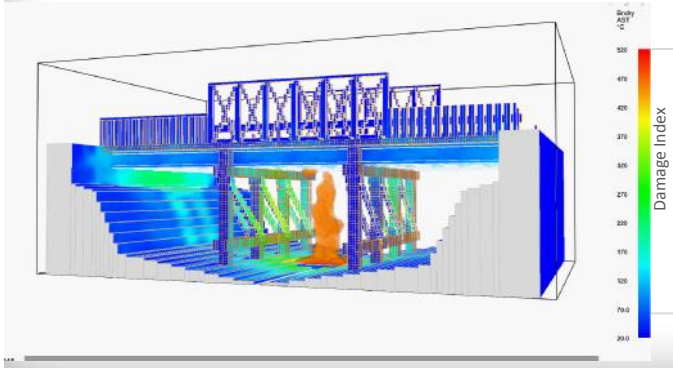


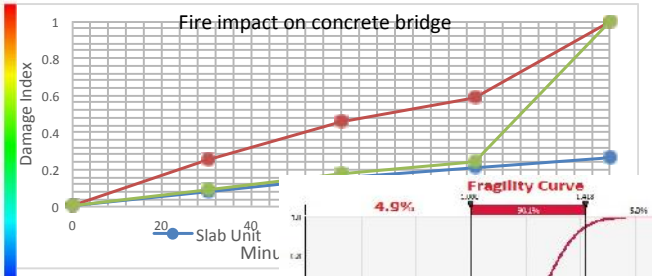
Post-tensioned box-girder bridge



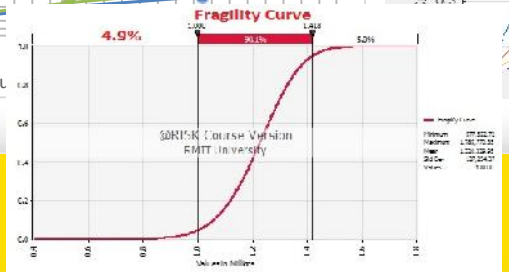


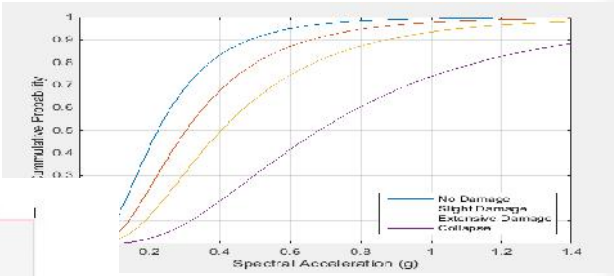






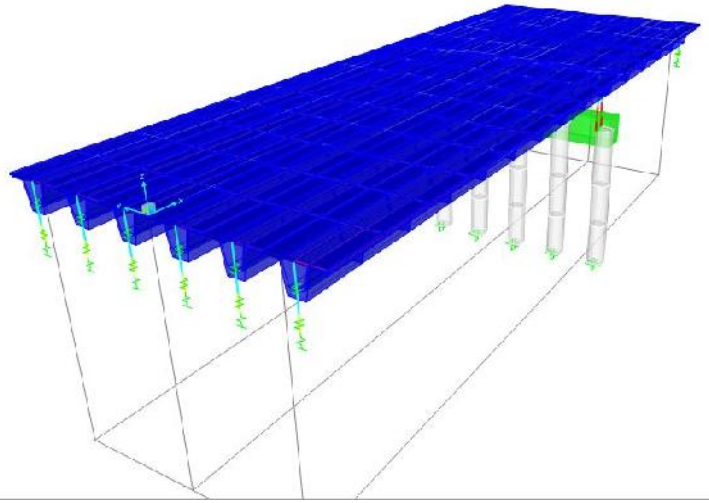
Fire impact on concrete bridge

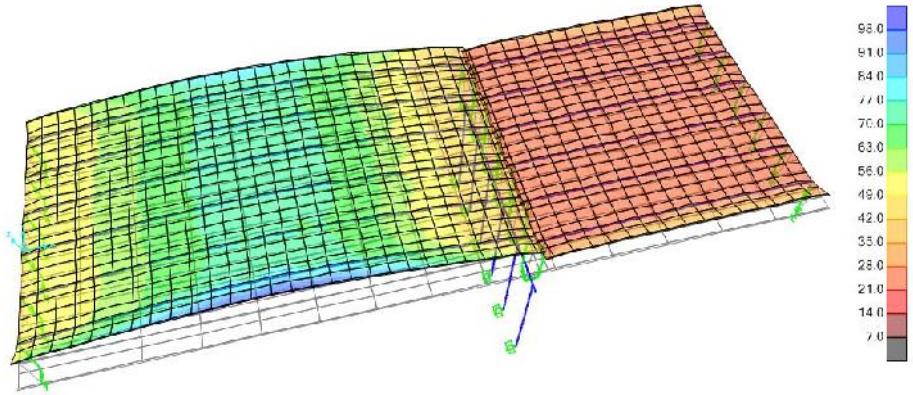




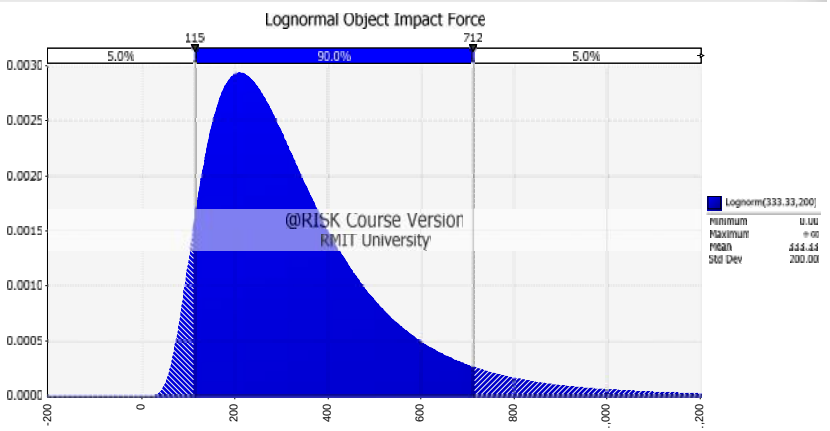
WAY FORWARD – HOW DOES IT ALL INTEGRATE?

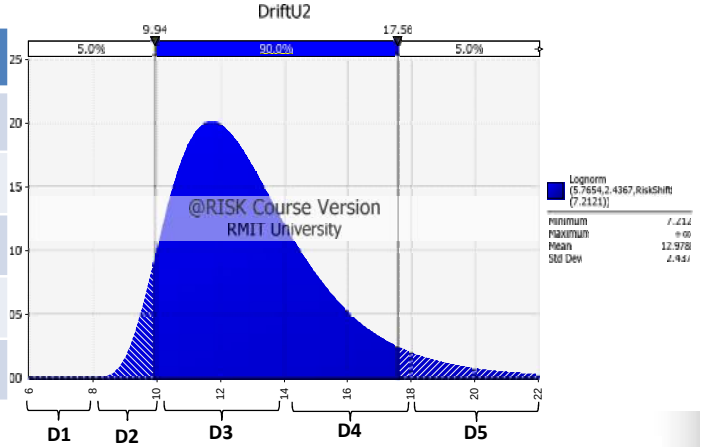
CASE STUDY - SUPER - T BEAM

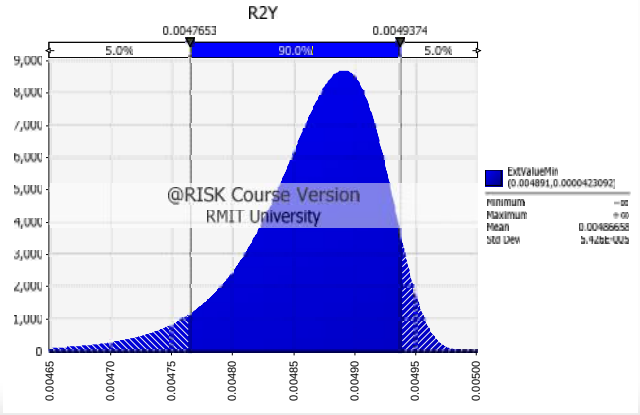




Damage	Probability
D1	0.01%
D2	5.6%
D3	67.2%
D4	23.2%
D5	4%

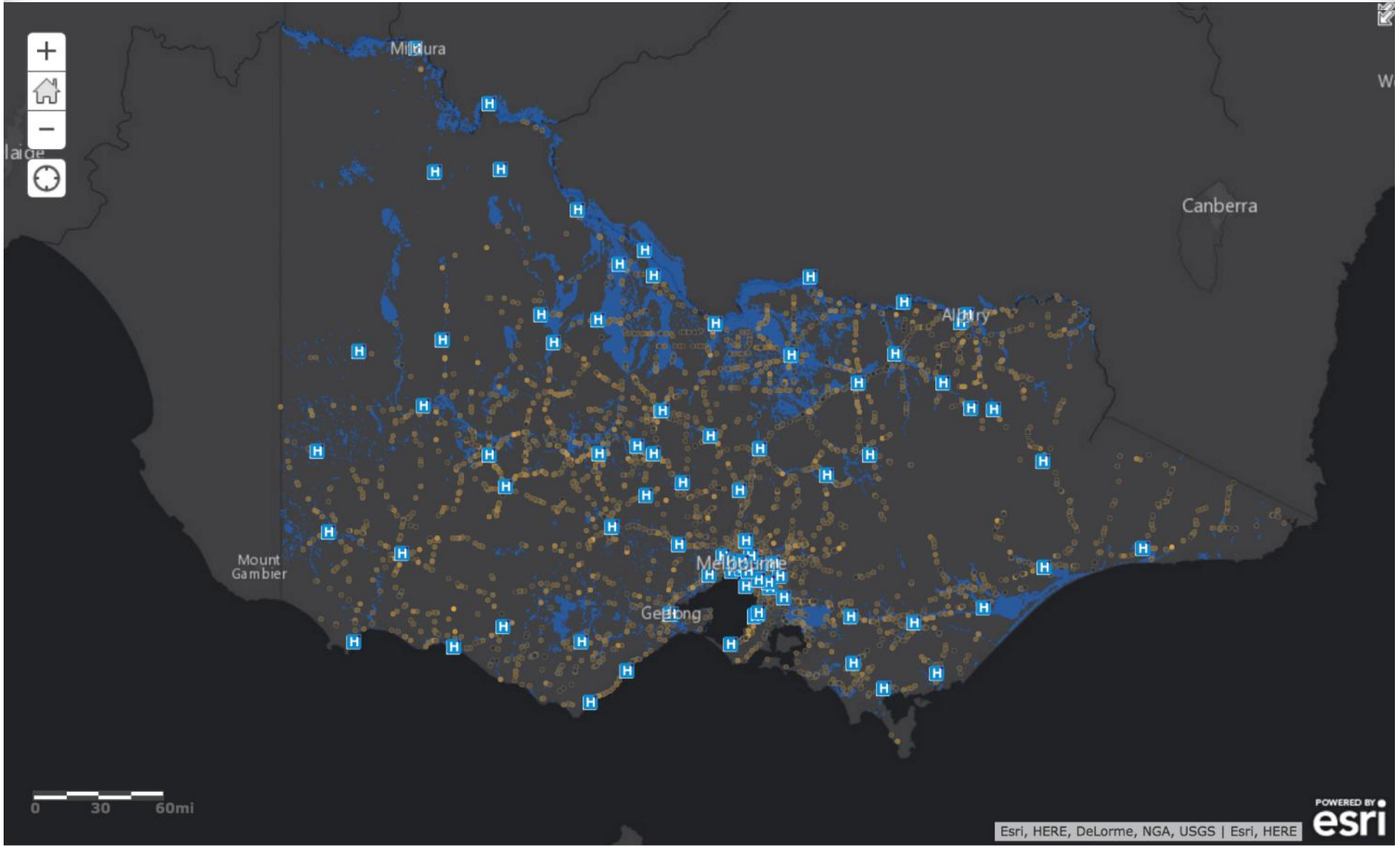






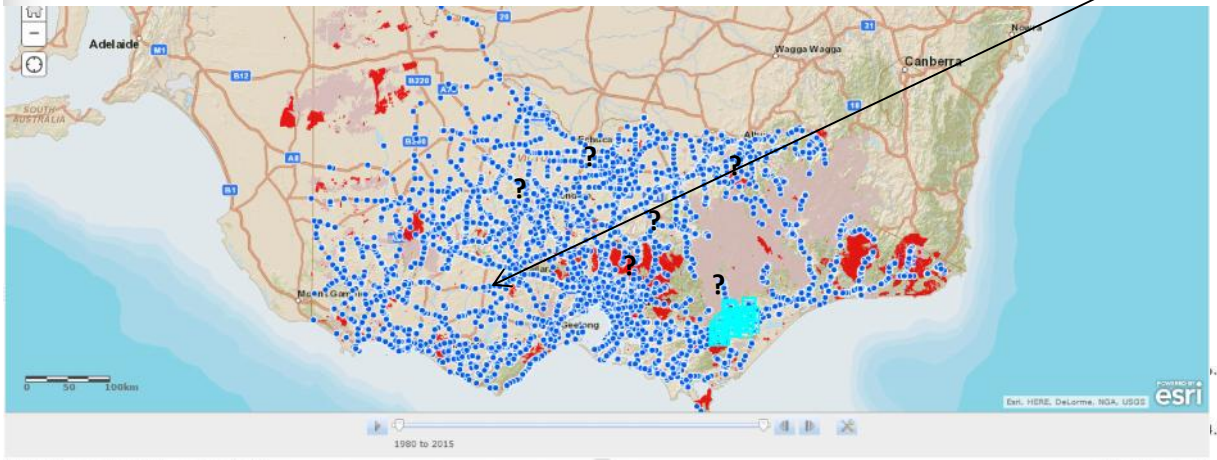
WAY FORWARD – GIS INTEGRATION AND STATE-WIDE EVALUATION OF ROAD STRUCTURES

1% AEP Flood



WAY FORWARD

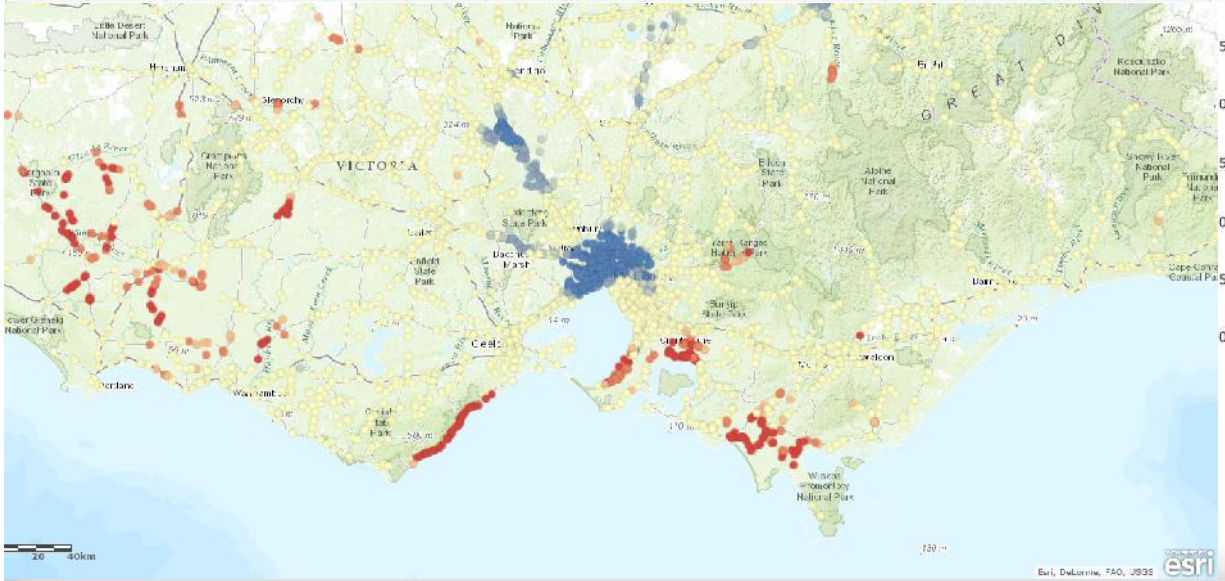
Damage	Probability ARI ??	Probability ARI ??	Probability ARI ??	...
D1	0.01%	~	~	
D2	5.6%	~	~	
D3	67.2%	~	~	
D4	23.2%	~	~	
D5	4%	~	~	

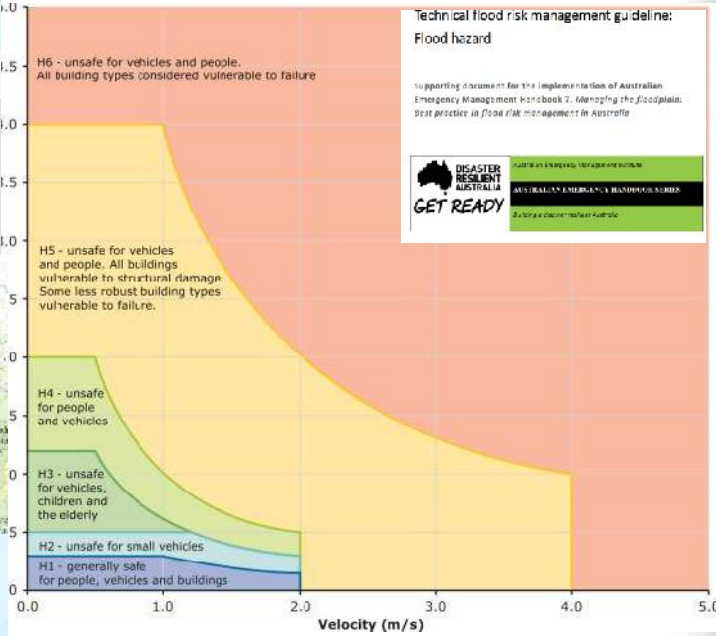


Bridge Structures (6,112 features, 104 selected)

Table Options

ID_STRUCTURE	BRIDGE_RATIN	BRIDGE_TYPE	BRIDGE_TYPE	COLLOQUIAL_N	COLLOQUIAL_N	COLLOQUIAL_N	FEATURE_CRO	FEDERAL_CAT	MATERIAL_CD	MIN_CLEARAN	NO_SPANS	OVERALL_LEN	OVERALL_WID	STRUCTURE_
SN1350	40.00	SE	ROAD OVER SEASONAL WATERCOURSE				UN-NAMED WATERCOURSE				1	1.80	61.40	SC
SN1353	1.00	SD	ROAD OVER PERENNIAL WATERCOURSE				MUDDY CREEK		SP		2	40.80	13.00	SB
SN1354	8.00	SE	ROAD OVER				UN-NAMED		SR		4	4.80	46.50	SC





QUANTIFYING ECONOMIC CONSEQUENCES

Direct

- Loss of lives
- Injuries
- Damage to cultural/asset heritage
- Psychological distress

- Damage to road structures
- Damage to vehicles
- Damage to utility systems
- Debris and deposition clean up costs

Intangible

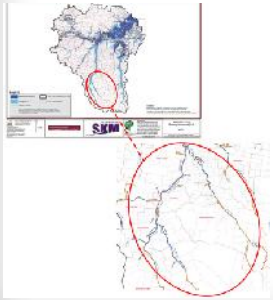
Tangible

- Loss of confidence/trust in authorities
- Loss of jobs (social disruptions)
- Community disorder

- Cost of traffic/transport disruption
- Business interruption due to the loss of the road
- Loss of incomes

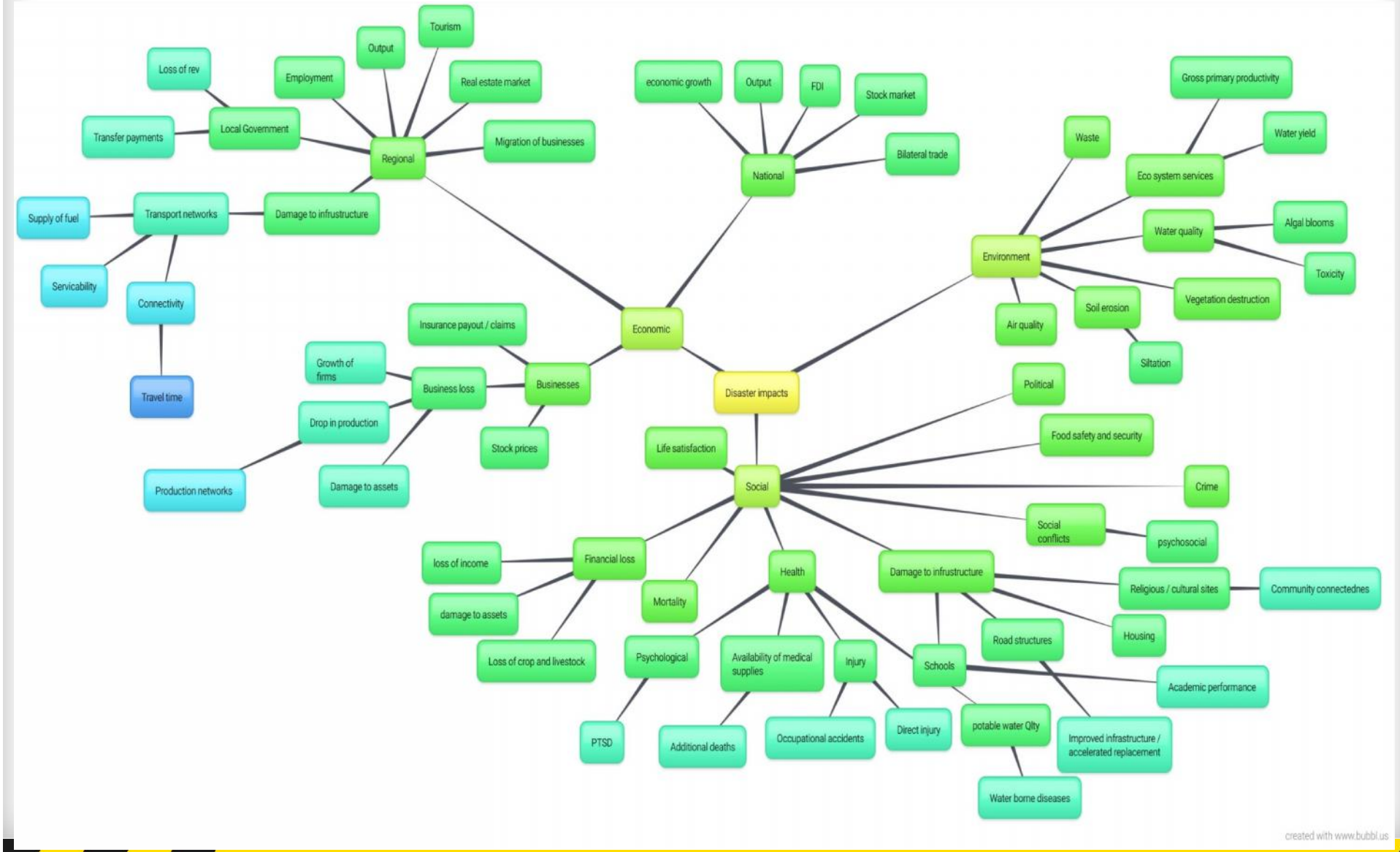
Indirect

COMMUNITY IMPACT STUDY



TRIPLE BOTTOM LINE STUDY IN PROGRESS …

IMPACTS ARE NOT ONLY FINANCIAL…



IMPACTS OF ROAD FAILURE

	Type of impact	
Measurement	**Direct**	**Indirect**
Tangible (Economic)	Damage to infrastructure Damage to vehicles Clean-up and debris disposal costs Disaster and reconstruction aid	Increase in travel time Business disruption Loss of individual income Loss of revenue to public transport operators Cost of alternative accommodation Increased employment during reconstruction
Intangible (Social)	Death and injury Loss of items of cultural significance Psychological impacts	Inconvenience and disruption to community Psychological impacts Loss of confidence in authorities
Intangible (Environmental)	Loss of biodiversity Loss of fauna and flora Deposit of fertile soil	Resource use for reconstruction Incremental emissions during reconstruction

ENGAGEMENT

WAY FORWARD & PROJECT UTILISATION

Three main Utilisation outcomes

1) Map of vulnerable structures in GIS (integration with VicRoads VMap)
   a) Generic methodology for calculating vulnerability
   b) Coverage of major failure modes

2) Prioritisation for funding allocation based on community needs and vulnerability of bridges
   a) Strengthening methods
   b) Incorporation of hazard maps and adjustment of weightings
   c) Social & environmental impact identification
   d) Economic impact consideration

3) Floodway design guide
   a) Understanding failure of different designs
   b) Practitioners view point on resilient designs
   c) Changes to design considering resilience
   d) Endorsement by Austroads and IPWEA

THANK YOU

DR. YEW-CHIN KOAY
VICROADS

Contribution to the project

Attend monthly project meeting
Working closely with the researchers and PhD candidates
In kind and cash contributions
Secondment and placement program
Develop working relationship

Utilisation of the project outcomes

Identify the industry need and gap
Complimentary the skill sets between engineers and researchers.
Mitigation the risk and prevention of failure.
Knowledge capture and transfer
Contribute to the community
Strengthen / improve the practice and requirements.