Integrated Deterioration Method for Predicting Long-term Bridge Performance: Case Studies

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Griffith UNIVERSITY

SIAMA
SMART INFRASTRUCTURE ASSET MANAGEMENT AUSTRALIA

Authors

Dr Guoping Bu
Research Fellow
Griffith School of Engineering, Griffith University, Queensland, Australia
g.bu@griffith.edu.au

Dr Jaeho Lee
CEO & CTO
Smart Infrastructure Asset Management Australia (SIAMA) Research and Development Pty Ltd
j.lee@siama.com.au

Dr Hong Guan
Associate Professor, Griffith School of Engineering, Griffith University
h.guan@griffith.edu.au

Professor Yew-Chaye Loo AM
Internationalisation Director for Sc, Envi, Eng & Tech Group, Griffith University
Chair, Board of Directors, SIAMA R&D Pty Ltd
y.loo@griffith.edu.au

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BACKGROUND -

- Why Bridge Asset Management (BAM)?
- What is Bridge Management System (BMS)?

Number of Bridges in AU & NZ

Bridges by road type and age – Australia, 2003 (RoadFact 2005, Austroads)

	National Highways (2003)		Arterial roads (2003)		Local roads (1996)	
Construction Era	No. of bridges	Total areas (m^2)	No. of bridges	Total areas (m^2)	No. of bridges	Total Areas (m^2)
Post – 1976	1,556	1,092,063	3,877	2,706,935	4,194	533,461
1948 – 1976	1,026	496,611	5,430	2,184,182	4,374	552,162
Pre - 1948	154	48,178	1,805	572,239	14,652	1,283,792
Total	2,746	1,636,852	11,112	5,463,356	23,220	2,369,415

Bridges by type – New Zealand, 2003 (RoadFact 2005, Austroads)

		Single lane bridges	Speed restricted bridges	Weight restricted bridges	Timber bridges	Other bridges
State Highways	Number of bridges	180	12	4	16	3,731
	Length of bridges (m)	13,265	955	364	1,250	125,367
Local roads	Number of bridges	7,387	101	503	1,076	4,321
	Length of bridges (m)	140,868	3,148	11,934	14,854	54,860
Total	Number of bridges	7,567	113	507	1,092	8,052
	Length of bridges (m)	154,132	4,103	12,298	16,104	180,227

AUSTRALIAN TRANSPORT INFRASTRUCTURE STATISTICS

- **800,000 km of public roads (**Road Facts 2005**)**
- **37,000 bridges (**Road Facts 2005**)**

- **Bridge maintenance, repair & rehabilitation (MR&R) costs**
  - **A$380M in 2003 (**National Transport Commission Annual Reports**)**
  - **A$1,600M in 2012 (i.e. 320% increase in 10 years)**

Bridge Asset Management (BAM)?

- To determine and implement the best possible strategy that ensures an adequate level of safety at the lowest possible life-cycle cost *(Frangopol et al., 2000)*

Bridge Management System (BMS)?

- A systematic and scientific way to obtain the best strategies for MR&R

Bridge Asset Management (BAM)

To determine and implement the best possible strategy that ensures an adequate level of safety at the lowest possible life-cycle cost.

(Frangopol et al., 2000)

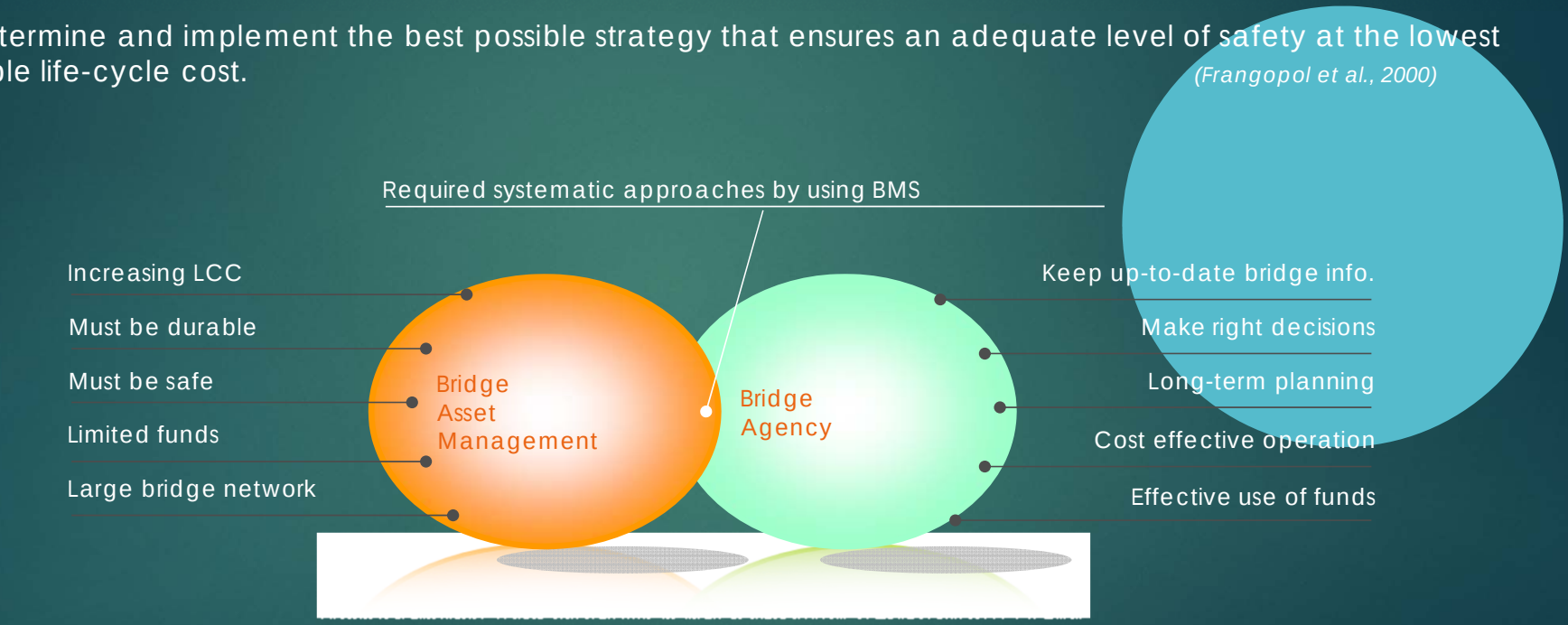
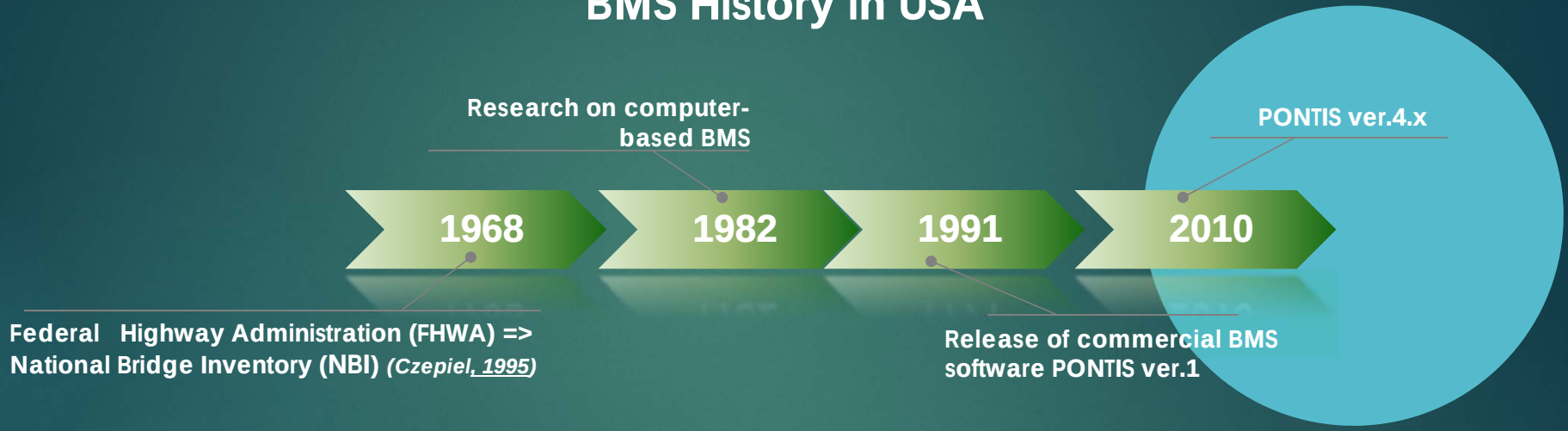


Figure 1. The Necessity for a BMS

(Das, 1998; FHWA, 1996)

Bridge Management System (BMS)

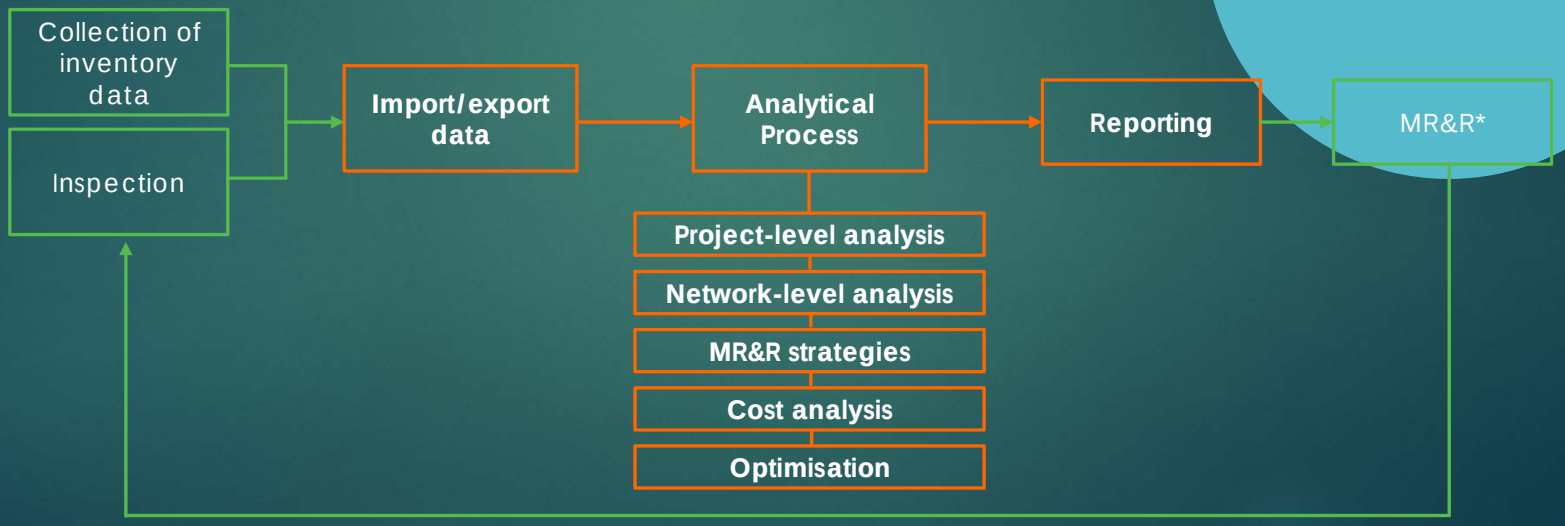
BMS History in USA



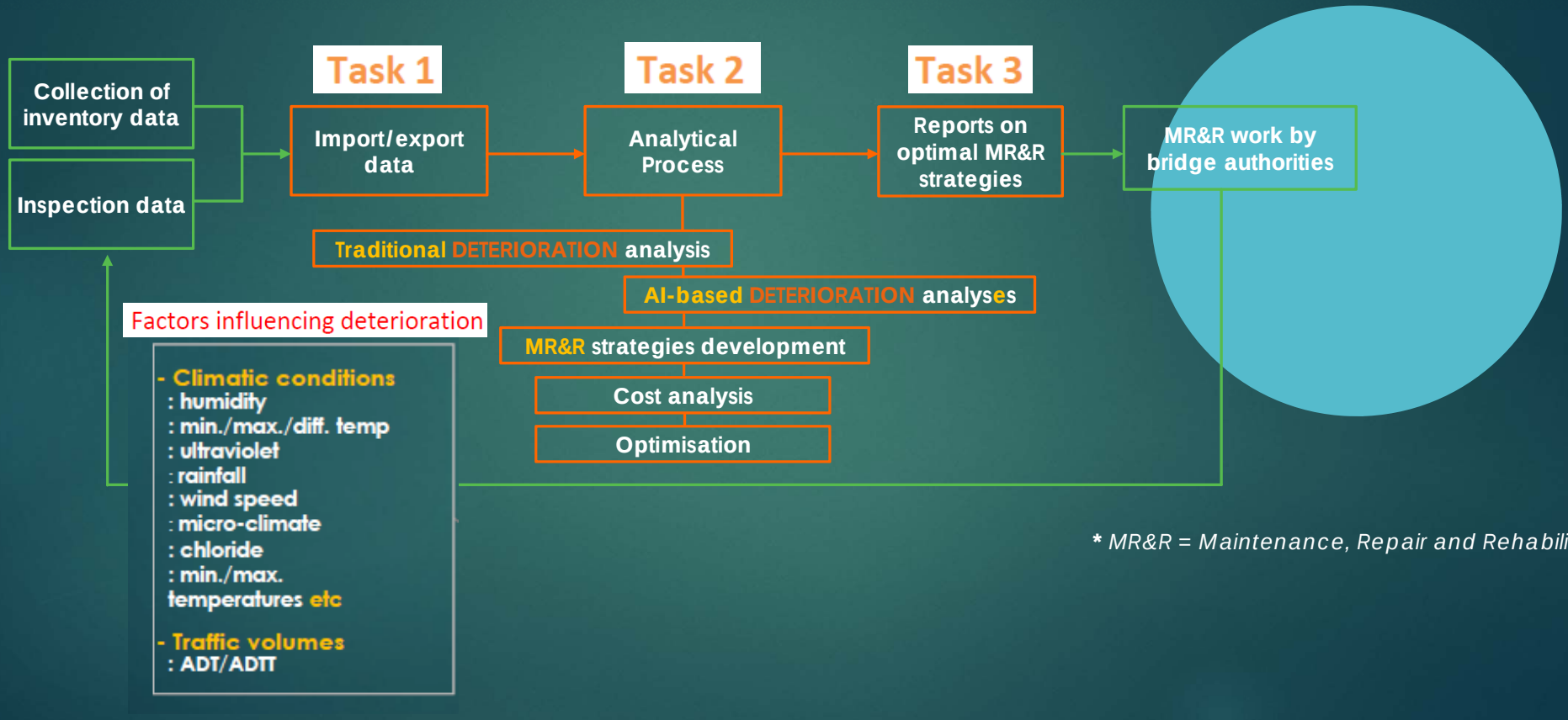
Bridge Management System (BMS)

- Bridge Management System (BMS)
  - to support decision-making that assures long-term health of network; and
  - to formulate maintenance programs in line with funding limitations.

- Major Tasks in Bridge Management



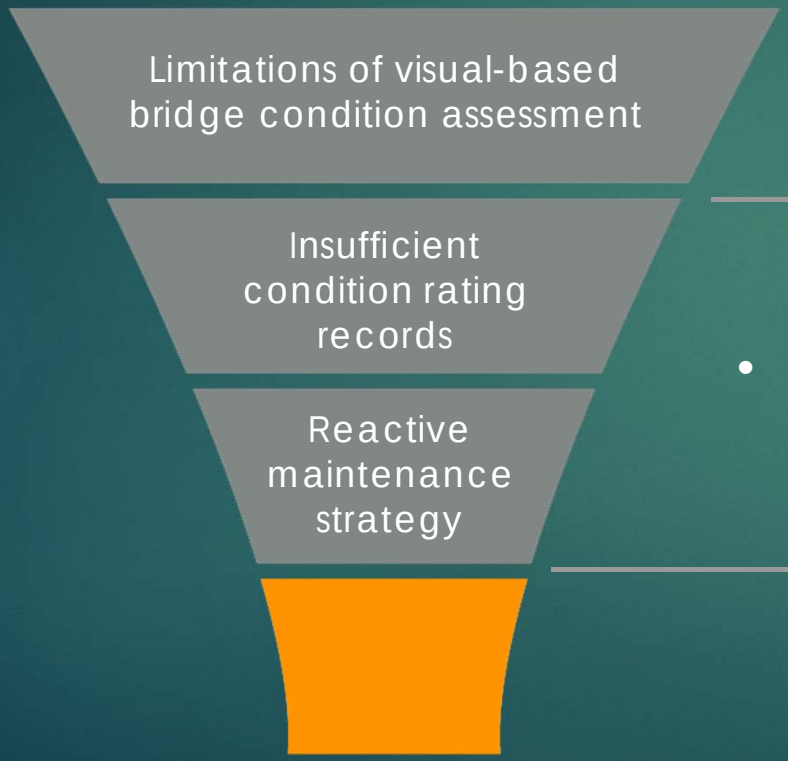
What does BMS do? Three main tasks!



* *MR&R = Maintenance, Repair and Rehabilitation*

Current BMS Issues

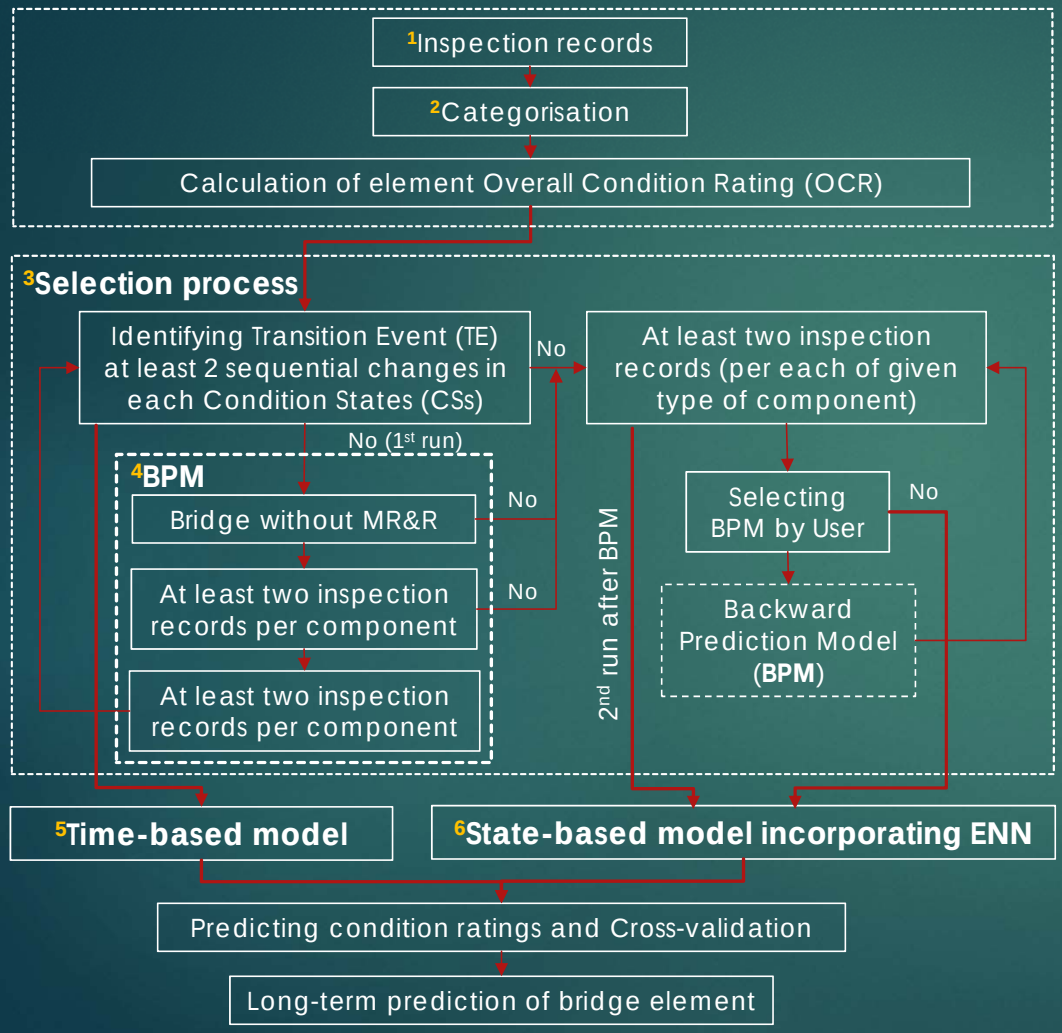
- Difficulties in bridge deterioration modeling in typical BMSs



- Inconsistent condition rating results
- Large gap between condition states (CSs)
- highly depending on experienced inspector

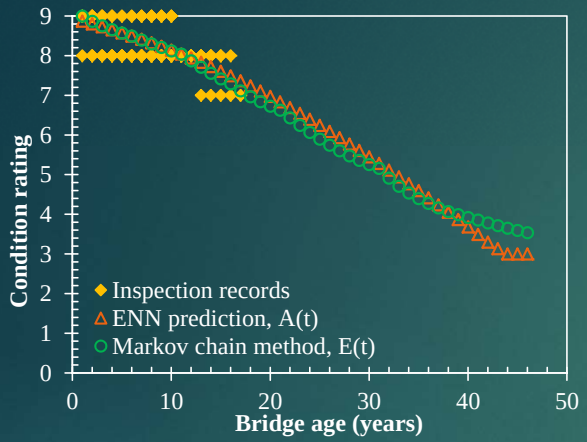
- Difficult to detect existing condition deterioration patterns for long-term prediction

Integrated Deterioration Prediction Method

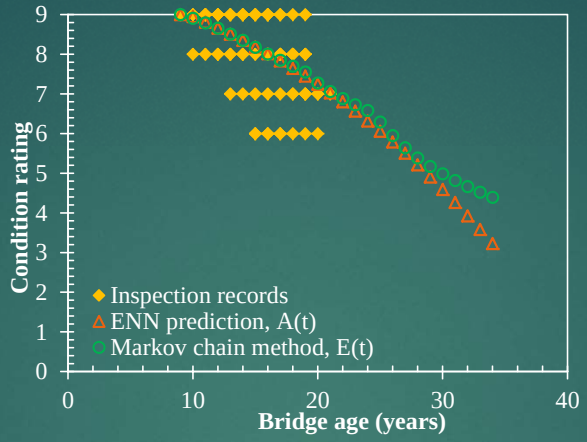


1. **Available** inspection records
2. Element types, material types, traffic volumes and construction eras **etc**.
3. Automatically select the **appropriate** deterioration model (i.e. time or state-based)
4. Backward Prediction Model (BPM) for generating **missing** historical inspection records
5. Generate a **probability density** function of time (using Kaplan & Meier method - stochastic)
6. Generate long-term **performance curves** (using Elman Neural Network technique - ENN)

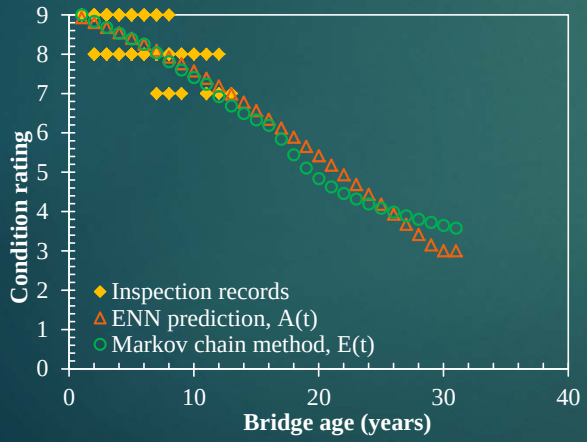
Integrated Deterioration Prediction Method



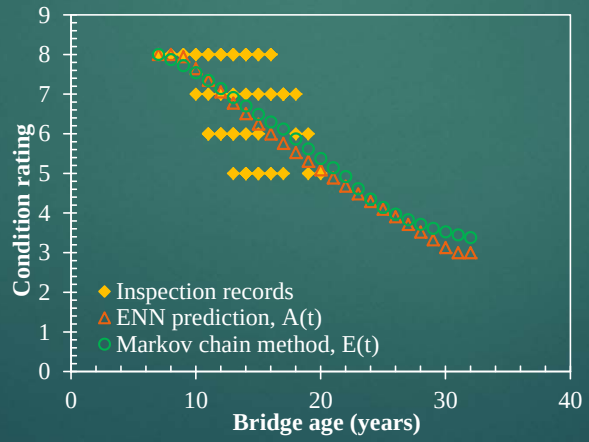
(a) Collector road bridge network of the 1991-2010 construction era



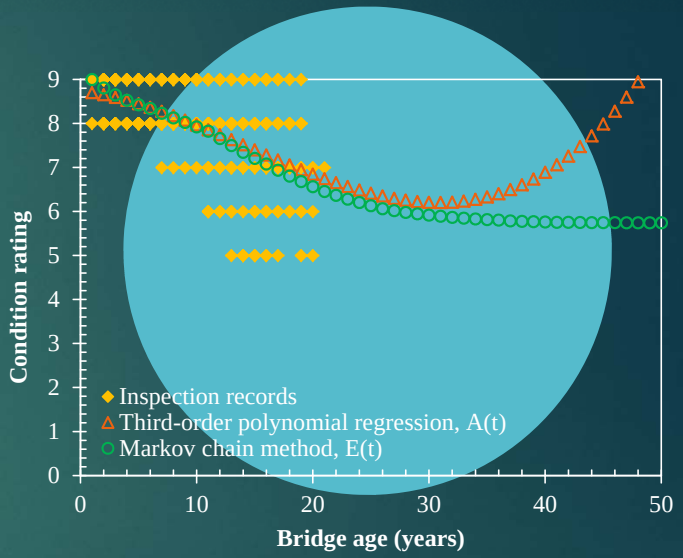
(b) Collector road bridge network of the 1971-1990 construction era



(c) Freeway bridge network of the 1991-2010 construction era

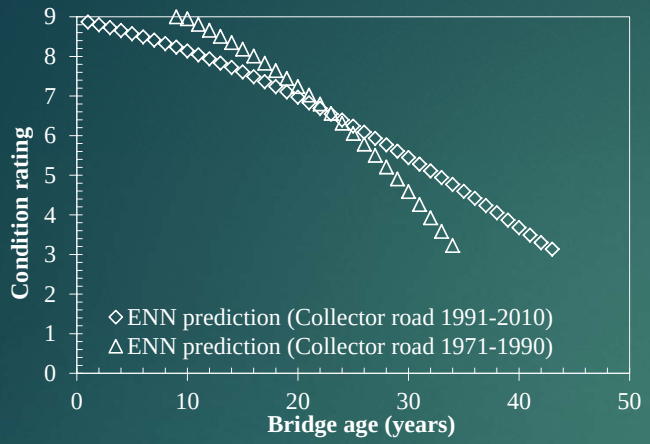


(d) Freeway bridge network of the 1971-1990 construction era

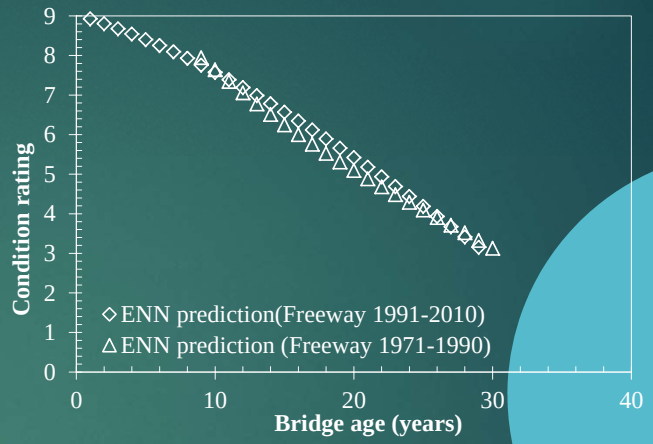


Data distribution and bridge performance curves

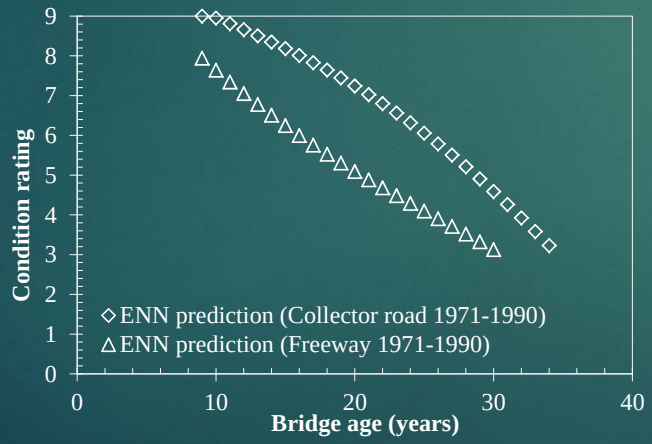
Integrated Deterioration Prediction Method



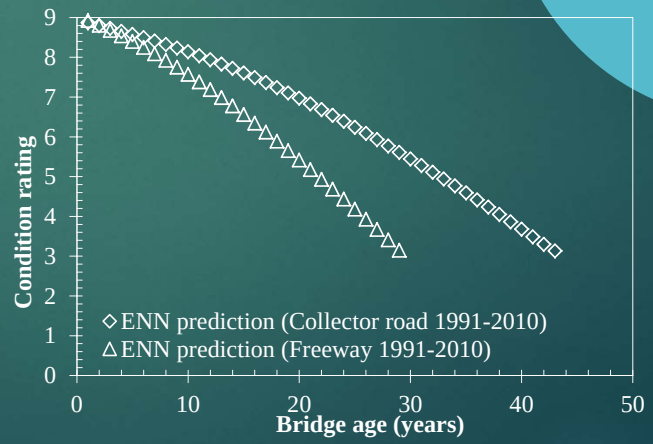
(a) Collector road bridge network of the 1971-1990 and 1991-2010 construction eras



(b) Freeway bridge network of the 1971-1990 and 1991-2010 construction eras



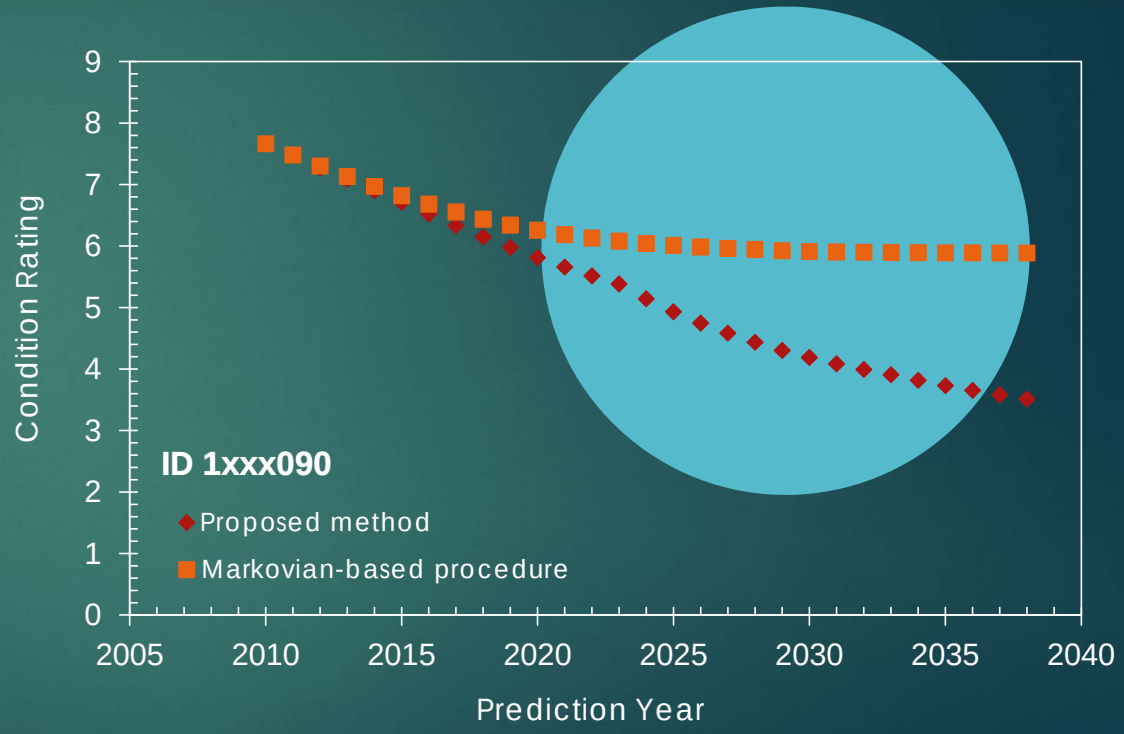
(c) Collector road and freeway bridge networks of the 1971-1990 construction era



(d) Collector road and freeway bridge networks of the 1991-2010 construction era

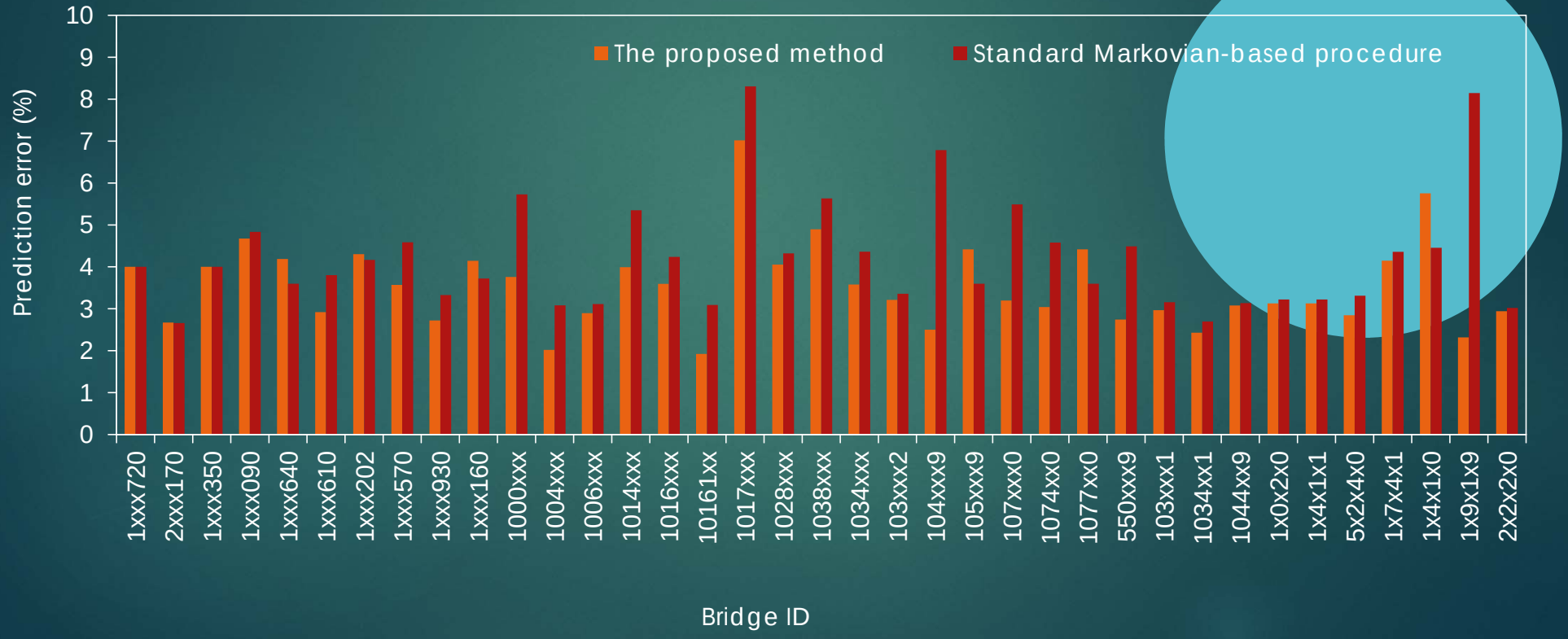
Long-term Bridge Performance Prediction

- **Case Studies**
  - National Bridge Inventory (**NBI**) datasets
  - Total of **40** bridges (**464** bridge substructure inspection records)
  - **315** records used as input data and remaining **149** records used for validation
- **Comparisons** of long-term deterioration predictions (see graph for an example – Integrated method's forecasts more meaningful)



Prediction comparisons

- **Comparisons of average prediction errors -** the proposed method is superior to the standard Markovian-based procedure



CONCLUSIONS & ON-GOING RESEARCH

- Bridge deterioration is a big problem & bridge safety is a real concern
- Reliable and sophisticated BMSs are urgently needed
- The “integrated deterioration prediction” method is the latest & best-performing technique developed by the Griffith-SIAMA team

- **SIAMA**-funded programs
  - Smart and objective inspection and data collection techniques
  - Automated inspection data generation processes (incorporating pattern recognition)
  - Commercialisation

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SIAMA R&D Pty Ltd

THANK YOU!


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