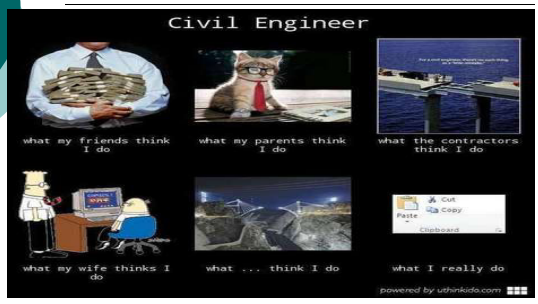
What is risk ?

- The likelihood of specific effect within a specified period
  - Complex function of probability, consequences and vulnerability

2

What does Civil Engineer do?



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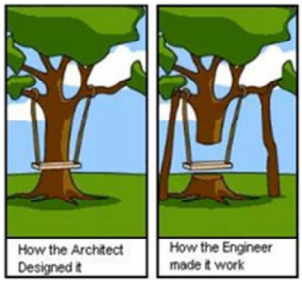
The Designers



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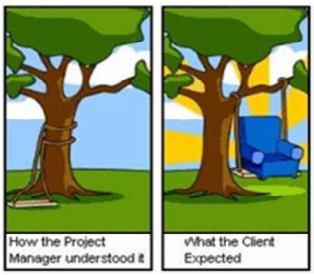
The Management



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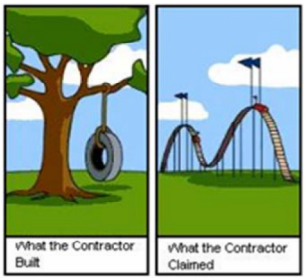
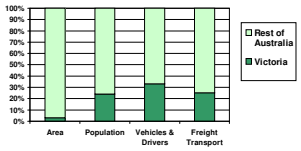
The Contractors



6

Victoria in Perspective

- 228,000 km^2
  - 3% of Australia
- 4.8 million people
  - 24% of Australia
  - 70% in Melbourne
- 4.4 million motor vehicles
  - 33% of Australia
- 3.5 million drivers
- 460 million tonnes of freight
  - 25% of Australia
- 155,000 km of roads
- 50 billion km of travel
  - 50% of arterial road travel in Melbourne



8

Roads in Australia

Road Type	Length (km)	Network (%)	Travel (%)
National highway (1)	18,600	2.5	14.2
Rural arterial (2)	94,900	11.6	21.6
Urban arterial (2)	12,400	2.3	39.6
Rural local (3)	600,700	73.2	6.3
Urban local (3)	84,800	10.4	18.3
All road types	**811,400**	**100.0**	**100.0**

(1) – funded by Commonwealth, managed by States
(2) – funded & managed by States
(3) – funded and managed by Local Government

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Roads in Victoria

Road Type	Length (km)	Network (%)	Travel (%)
National highway	1,010	0.9	8.9
Rural arterial	18,060	10.2	21.8
Urban arterial	3,180	3.2	51.7
Rural local	106,100	67.3	5.2
Urban local	26,400	16.8	12.4
All road types	**154,750**	**100.0**	**100.0**

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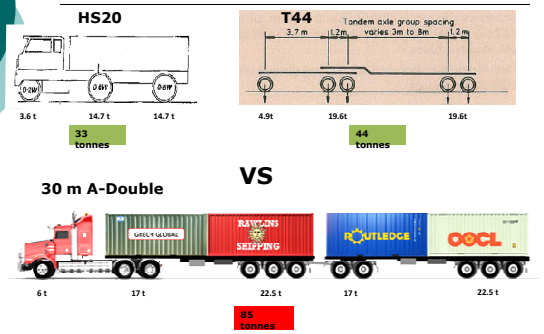
Engineering Risk Analysis

Challenges

Challenges

- A significant proportion of today's civil infrastructure is old and deteriorating
- The ability of many structures to sustain much of the modern applied loads is becoming a challenge
- There is a strong need for structural retrofitting or even reconstruction

Freight Vehicles



Vehicle Prior to 1950

15 Tonne - Pre 1950 Bridge Design Vehicle – 3m Axle Spacing

Freight Vehicles

CityLink Southern Link
77.5 tonne

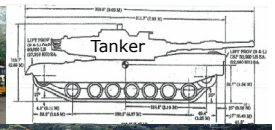
WRR Upgrade
110 tonne (75% SM1600)

Design Code SM1600 – 160 tonne

Current Legal:
68 tonne B-Double

Typical Heavy Load Permit Vehicles

Heavy Permit Low Loader



Tanker

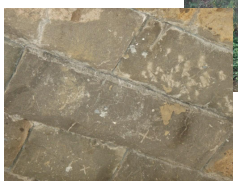
Heavy Platform

Climate Change

Sea level will increase 0.8m by 2100
Today's 1:100 storm will occur every 50 years

Climate Change

Structural Deterioration



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Structural Deterioration

Structural Deterioration

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Engineering Risk Analysis

Building Structures

Rana Plaza, Dhaka, Bangladesh

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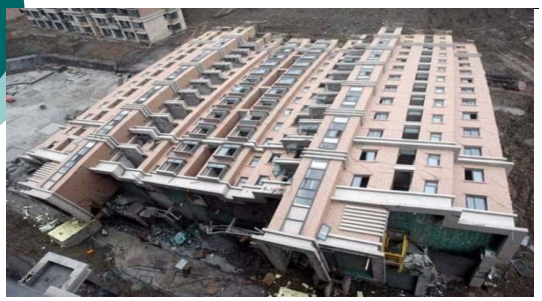
Shanghai, China



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Trengganu, Malaysia

25

Engineering Risk Analysis

Bridge Structures

I-35 Mississippi River Bridge, US

It's fine to celebrate success, but it is more important to heed lessons of failure

- Bill Gate

27

Kobe Earthquake, Japan

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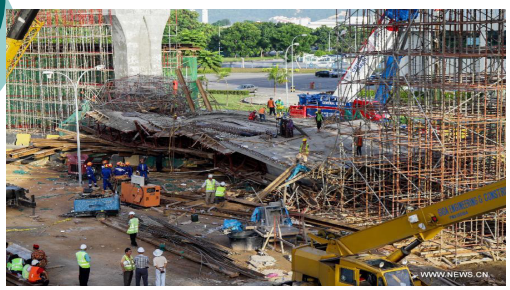
Motorway Bridge, Heilongjiang, China

29

Queensland, Australia

30

Penang Second Bridge, Malaysia



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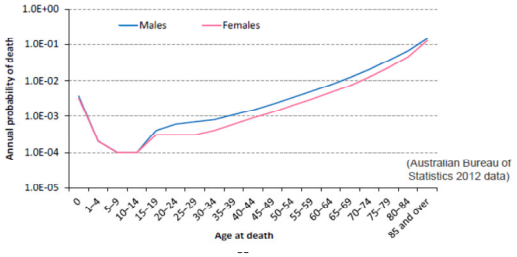
Engineering Risk Analysis

Risk Analysis

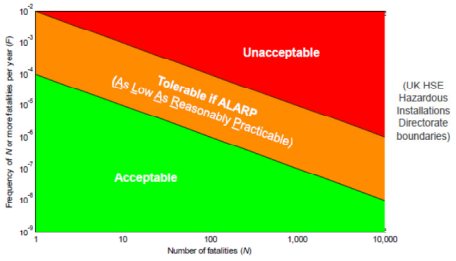
Individual Risks

- Risk to single person exposed to a hazard
- The background risk is at best $1x10^{-4}$



Societal Risks

- Risks to groups of people from major incidents – using *FN curves*



(UK HSE Hazardous Installations Directorate boundaries)

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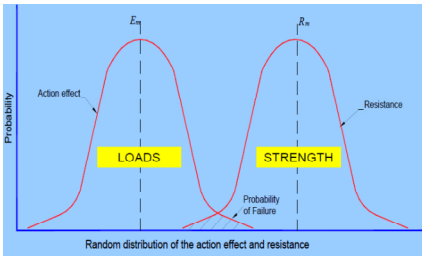
Reliability Theory

- Actual load on the structures vary, as does the strength of structures



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Safety, Theory and Practice

- There are known knowns
  - Things we know we know
- There are known unknowns
  - Things we know we don't know
- There are also unknown unknowns
  - Things we don't know we don't know

Donald Rumsfeld

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Some Risks

- Fundamental conceptual errors
- Design errors, omissions
- Fabrication, manufacturing defects
- Construction defects
- Materials defects
- Operational errors

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Typical Characteristics of Structural Risk

- Lack of competence
- Fixings generally
- Tensile components
- Lack of engineering appreciation
- Poor communications
- Over reliance on computing
- Temporary works
- Free standing walls
- False documentation
- Lack of maintenance

Risk increases when factors are combined

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Benefits of Learning

- Protection of lives and assets
- Improvements to codes and regulations and best practice
- Avoid the trauma of being involved with collapse
- Reductions in cost to all involved in a failure
- Ethical considerations
- Improvements to corporate money

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Engineering Risk Analysis

Building and Structure Design – Worksafe Victoria

Safe Design for Work

- Section 28 OHS Act 2004
- 'Designer Duty'
- Duty to apply a systematic approach
- Who is a Designer?
- Whose workplace
- Complementary and in addition to the Contractor's Duty
- Wider context - s21, s23, s26 – provision of a safe workplace

Safe Design for Work

- s2 of the Act includes four objectives of which the second is:

'Eliminate, at the source, risks to the health, safety or welfare of employees and other persons at work'

'…at the source…' means during the design phase

- s4 of the Act includes the following principle:

'Persons who control or manage matters that give rise or may give rise to risks to health or safety are responsible for eliminating or reducing those risks so far as is reasonably practicable'

Designers are 'Persons who control or manage matters…'

Safe Design for Work

A person who designs a building or structure or part of a building or structure who knows, or ought reasonably to know, that the building or structure or the part of the building or structure is to be used as a workplace must ensure, so far as is reasonably practicable, that it is designed to be safe and without risk to the health of persons using it as a workplace for the purposes for which it was designed

Safe Design for Work

- Whose Workplace is it?
- People who inspect, patrol, clean, maintain bridges, roads and the things in them (VicRoads' and its contractors' employees)
- Service company employees who inspect and maintain cables and pipes on or adjacent to the highway
- Tram, railway and bus drivers and the inspection and maintenance teams that work on tram and rail infrastructure in the highway
- Emergency services – police, fire, ambulance
- Waste-collection teams
- Posties
- Professional drivers – truck, taxi, delivery etc
- Designer-duty discharged by normal design methods and Road Safety Audit

Safe Design for Work

- Who is a Designer?
- Anyone who contributes to the design and hence the hazards associated with it
- Potentially everyone here in this room and everyone who works at VicRoads
- Project delivery engineers, designers, contractors, PRC etc etc
- You don't need to have 'Designer' in your job title!
- What is a Workplace?
- Bridges, road-related structures, roads, landscape areas – any part of the highway that has to be built, inspected and maintained

Safe Design for Work

- What is reasonably practicable?
- This is a legal term of particular importance
- How WorkSafe applies the law in relation to Reasonably Practicable
- A guideline made under section 12 of the Occupational Health and safety act 2004
- Designers not compelled to eliminate all hazards
- Designers allowed to weigh-up the hazards vs the methods and cost of controlling

Safe Design for Work

- Section 20(2) of the Act - regard must be had to the following in determining what is reasonably practicable in relation to ensuring health and safety:
- (a) the likelihood (probability) of the hazard or risk concerned eventuating;
- (b) the degree of harm (consequence) that would result if the hazard or risk eventuated;
- (c) what the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;
- (d) the availability and suitability of ways to eliminate or reduce the hazard or risk;
- (e) the cost of eliminating or reducing the hazard or risk.

Safe Design for Work

- Designers must apply a process of design risk (hazard) management
- Essential steps:
  - Consultation
  - Hazard identification (high-risk work)
  - Hazard management (add/amend drawings to address high-risk items)
  - Residual hazards (hazards still in design)
  - Communicate (to end-user via drawings and documents)
  - Record

Safe Design for Work

High-risk construction work

- Risk of falling more than 2m
- Telecommunications towers
- Demolition
- Removal or disturbance of asbestos
- Structural work where temporary support will be used to prevent structural collapse
- Confined spaces
- Work in a trench or shaft deeper than 1.5 metres
- Tunnelling
- Explosives
- Work on or near gas mains, chemical, fuel or refrigerant lines, or electrical services.
- Contaminated or flammable atmospheres
- Tilt-up or precast concrete
- Work on or next to roads or railways
- Mobile plant
- Artificial extremes of temperature
- Work in, over or near water
- Diving

Safe Design for Work

- What can Designers do in practice?
- Think – how will the structure be built and how will it be inspected and maintained – find out if you don't know
- Apply the process carefully and consistently
- Consult with the 'end-user' and contractors – those who own and maintain the structure to learn about inspection and maintenance practices
- Hazard management - look for opportunities for improvement
- Communicate - make it clear on the drawings why certain features have been adopted

Safe Design for Work

- Construction Regulations
- Emphasis on elimination of hazards
- WorkSafe position statements
- Road Design Note Designing Safe Workplaces
- No known cases – 'wait and see'

Safe Design for Work

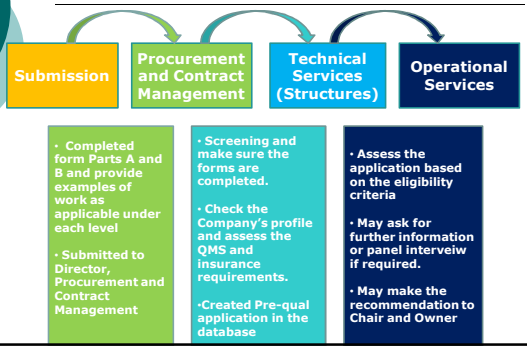
- Process standardises approach across organisation
- Ensures comparability
- Allows prioritisation
- However need to 'stand-back'
- Look for clear opportunities to eliminate or reduce significant hazards

Safe Design for Work

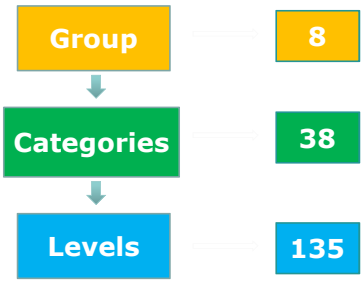
Engineering Risk Analysis

Pre-qualification

Pre-qualification Process



Pre-qualification Scheme



Pre-qualification Group

- Road and Bridge Construction and Maintenance
- Road and Bridge Design
- Traffic Management Services (Consultants)
- Traffic Management Services (Contractors)
- Pavement and Geotechnical Engineering
- Transport Planning and Project Assessment
- Other Professional Services
- Environment

Eligibility Criteria(Road and Bridge Design)

To be eligible, as a minimum, a Company must demonstrate

- Personnel experienced in the area of competency for the Pre-qualification level
- Previous relevant experience and satisfactory performance in the areas of competency described for the Pre-qualification level
- Quality systems certified as meeting VicRoads requirements and third party certified to AS/ANZ and ISO 9001:2000
- Evidence that the Company has a Victorian WorkCover insurance
- Appropriate levels of Professional Indemnity Insurance

Bridge Design – Simple Structures (SS)

Area of Competency

- Design of minor bridges and culverts
- Generally using standard precast components
- Generally bridges with spans less than 20 meters over waterways and roads other than freeways
- Basic retianing walls, sign structures and noise walls

Bridge Design – Complex Structures (CS)

Area of Competency

- Design of major bridges with complex foundations, structural components, construction operations and temporary works
- Generally bridges with spans in excess of 20 meters over freeways, large waterways and railways.
- Bridges comprising prestressed cast in situ concrete (box girders, voided slabs, etc) and bridges using welded plate girders
- Cable stayed, balanced cantilever, match-cast segmental, incrementally launched and steel & concrete arch structures
- Complex pedestrian bridges, sign structures and widenings

Proof Engineering – Structures (PE)

- Proof Engineering is a process of independent review and formal certification that a structure, as documented, can be constructed safely and will meet the specified requirements.
- This pre-qualification is awarded to companies but is conditional on the nominated representatives of the Company being directly involved in the assessment and issue of the PE's certificate
- Must nominate one or more individuals who will be directly involved in the review of the design and the proposed construction method and issue of the PE's certificate

Proof Engineering – Structures (PE)

Area of Competency

- Previous experience in proof engineering
- Qualifications as a practising professional structural engineer
- Extensive experience in positions of primary responsibility for the design and analysis of complex bridge structures
- Extensive experience in positions of primary responsibility for the analysis of temporary works and erection processes employed in construction of complex bridges.

Hydrologic and Hydraulic – Simple (SH)

Area of Competency

- Determination of catchment runoff
- Design discharges and appropriate bridge or culvert waterway together with any stream realignment
- Scour protection or similar works for structures over single, well defined water courses
- Minor flood plains

Hydrologic and Hydraulic–Complex (CH)

Area of Competency

- Larger and more complex catchments includes catchments that require use of flood routing techniques to determine design discharges
- Complex hydraulic design of minimum energy and super critical flow structures, energy dissipation components, sophisticated inlet/outlet works and sophisticated numerical modelling
- Major flood studies involving large catchments and flood plains with complex multi directional flow patterns
- Determination of locations and waterway areas of multiple bridges and culverts for roads crossing such flood plains.

Specific Eligibility Criteria
(Other Professional Services – BI2)

To be eligible, as a minimum, a Company must demonstrate

- Successful completion of the ARRB Level 2 Bridge Inspection course or an equivalent approved in writing by VicRoads for this purpose
- Extensive practical experience in inspection, construction, design, maintenance or repair of road structures
- Competency to judge the condition of structures and the importance of visual defects
- Facility to access advice from a qualified professional bridge engineer if required
- Attendance at a VicRoads Level 2 accreditation briefing Satisfactory performance in the accreditation briefing assignment

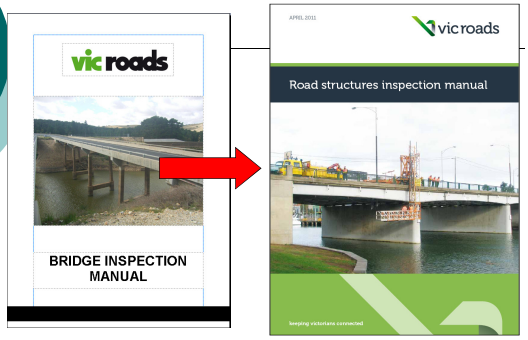
Bridge Inspection – Level 2 (BI2)

Area of Competency

- Visual inspection of bridge components to access their condition
- Reporting the condition and extent inspection of the structures components
- Identifying components that limit the performance of the structure
- Identifying the probable causes and factors of deterioration

Engineering Risk Analysis

Inspections



Bridge Inspection Levels

The policy identifies accountabilities for structure management and establishes requirements for a systematic program of inspections:

a) Level 1 - Routine Maintenance Inspection

b) Level 2 - Bridge Condition Inspection

c) Level 3 - Detailed Engineering Inspections

d) Monitoring

Level 1 Routine Maintenance Inspection

Purpose

- To check *general serviceability* of the structure for *obvious signs of defects* which may affect the *immediate safety* of road users
- To *identify maintenance* which can be undertaken immediately and/or schedule *routine maintenance* to be done at a later date

Level 2 Road Structures Condition Inspection

Purpose

- Identifying current maintenance needs
- Assessing the effectiveness of past maintenance treatments
- Modelling and forecasting future changes in condition and estimating future budget requirements

Level 3 Detailed Engineering Investigations

Purpose

- A combination of *theoretical analysis* and *field investigation*.
- Usually targets a specific issue relevant to an individual structure or class of structure.
- Provide improved knowledge of the condition, load carrying capacity, in-service performance and other characteristics that are beyond information that can be obtained from visual only.

Engineering Risk Analysis

Case Study

Bridge Over Loaded

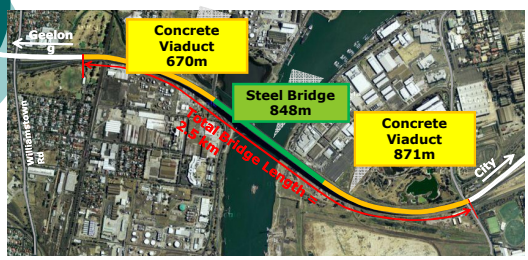
Corrugated Metal Structures

Cantilever Sign Structure

Base - cracked mortar and failed bolt

Incomplete ‘grout’ (mortar)

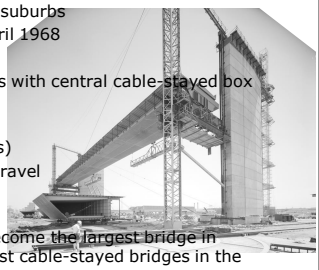
West Gate Bridge



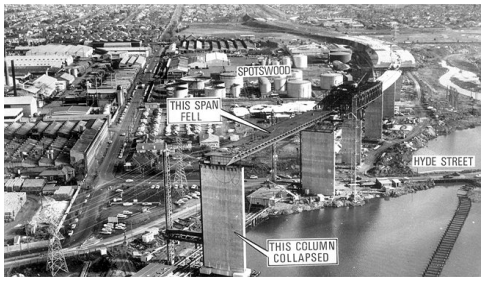
West Gate Bridge History

Construction

- Built to link East and West suburbs
  - Construction started April 1968
- Concrete approach viaducts with central cable-stayed box girder steel bridge
- Cost $220 million (in 1970s)
  - To be funded by tolled travel (60 cents per car trip)
- At the time, WGB would become the largest bridge in Australia, and one of longest cable-stayed bridges in the world



West Gate Bridge History



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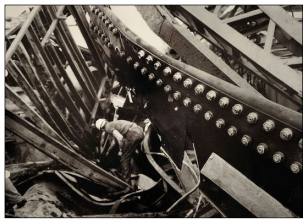
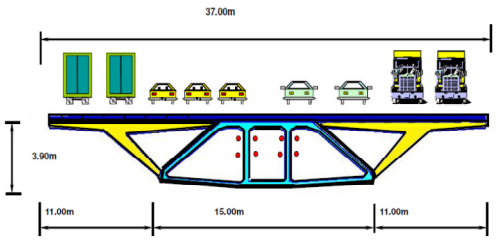
West Gate Bridge History

Collapse

- On 15 October 1970, Span 10-11 of the steel bridge (Geelong side) collapsed
- 35 workers were killed
- Royal Commission found that serious design flaws were present and a redesign of the bridge was ordered.
- Even today, the collapse remains Australia's worst industrial incident
- West Gate Bridge Memorial below Pier 9 remembers the tragedy



West Gate Bridge - Cross Section



Approach Viaducts

West Gate Bridge

Completion

- Opened to traffic in 1978
- Currently carries 195,000 vehicles per day – Melbourne's most critical east-west road transport link
- West Gate Bridge Management Team formed in 2012 to manage maintenance of the entire structure


Any Questions ?
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