Past Systems Projects

Rob Kirkpatrick

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Bother

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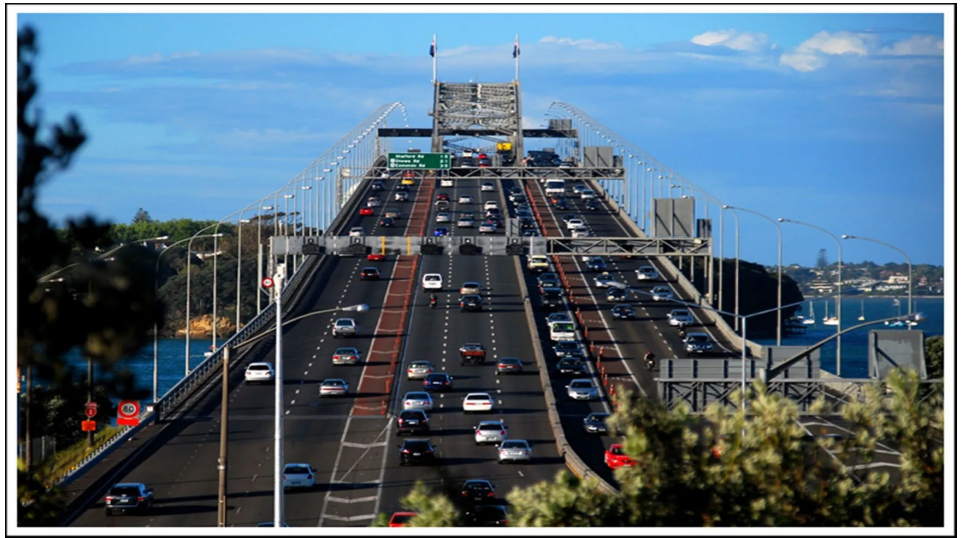
Auckland Harbour Bridge out for 18 months



Bother

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Cost exceed ~20 billion Christchurch Quake of 2011?

Overseas

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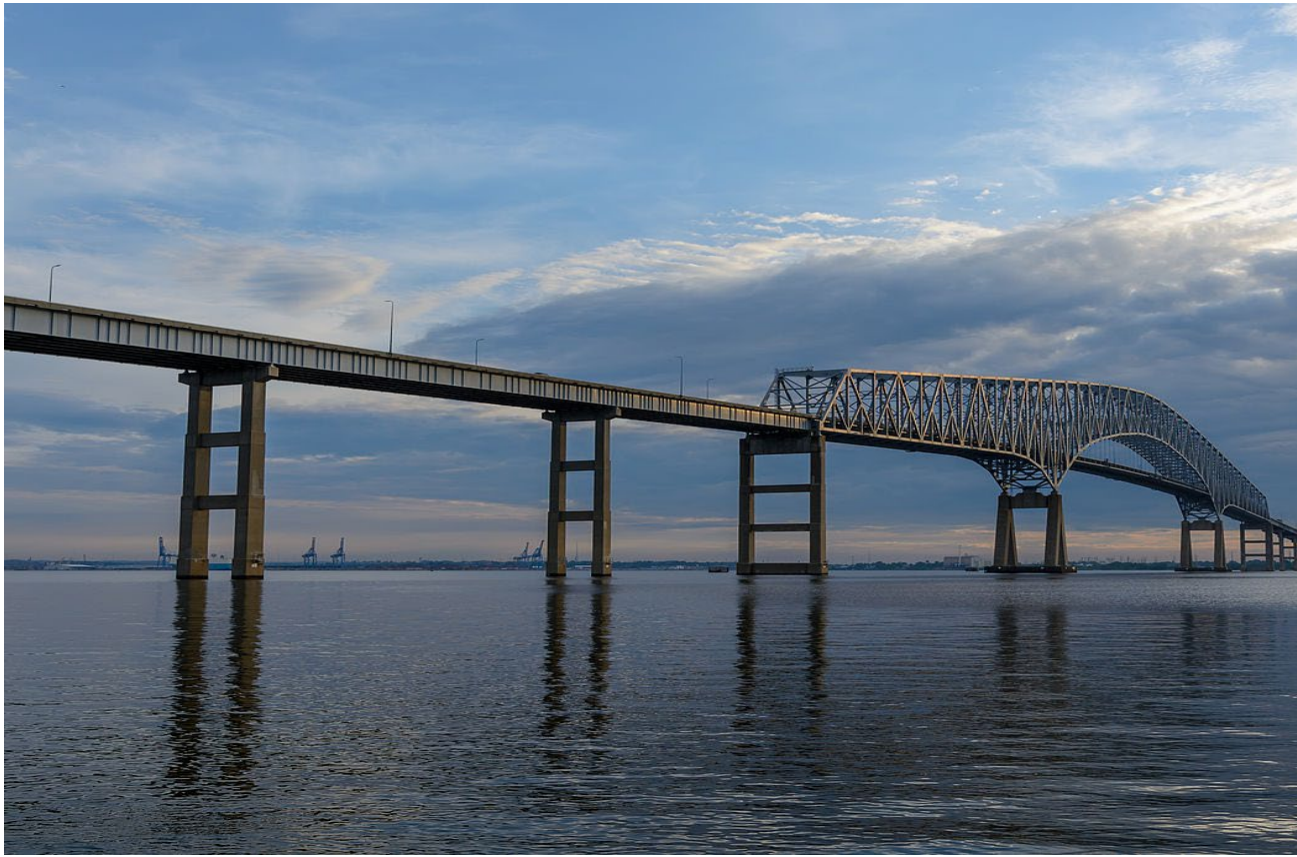
Baltimore Bridge
USA East Coast
Pre March 2024



Bother

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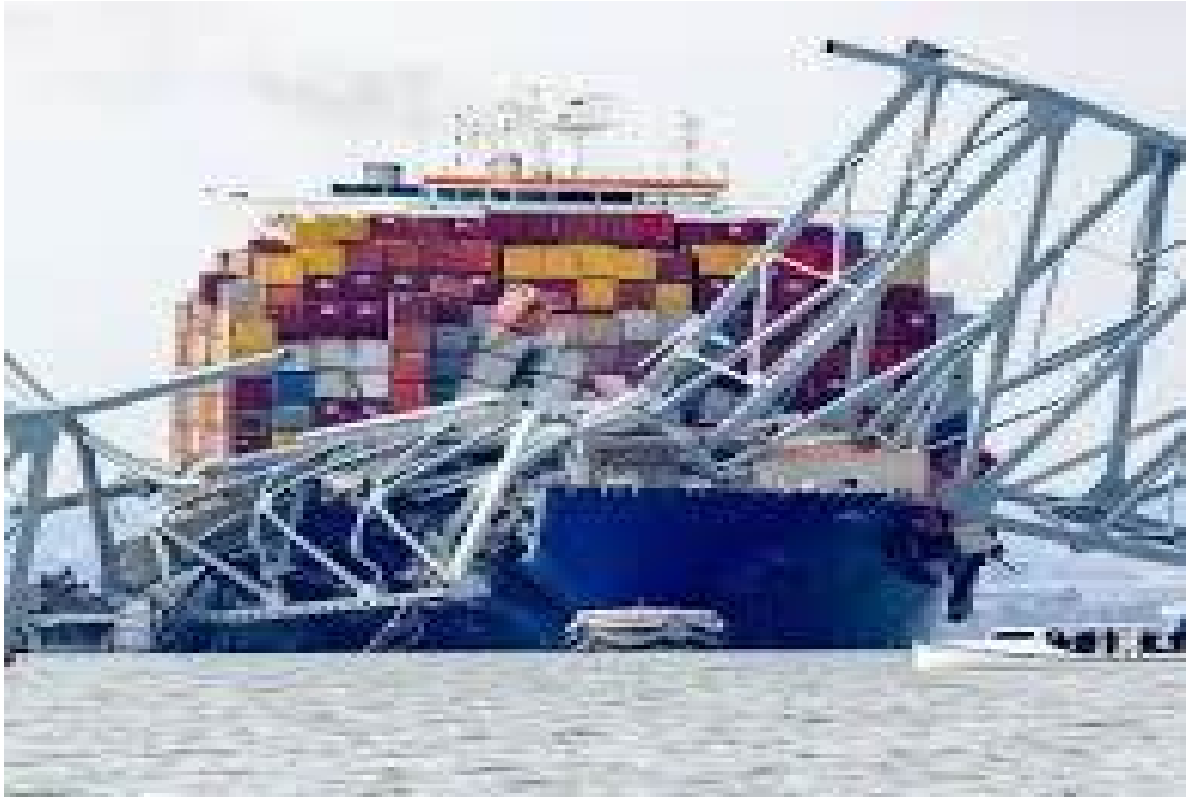
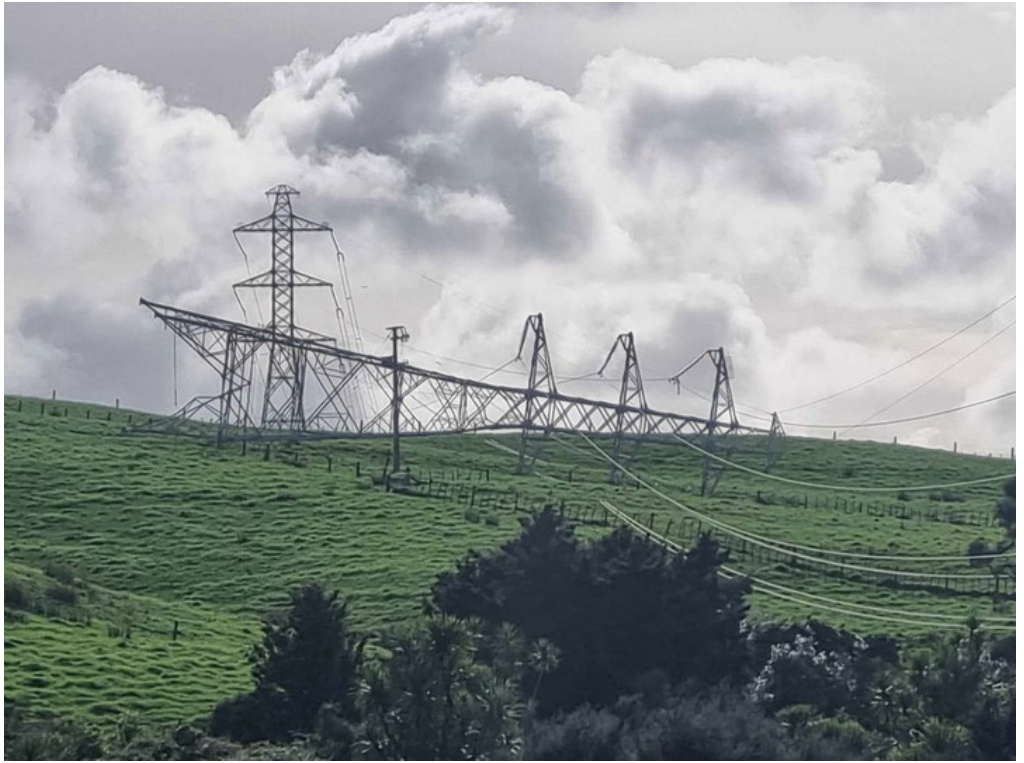
Baltimore Bridge
USA
March 2024



Bad things do happen by accident

Recent power pylon problem took out power to the far north of NZ. Contractors removed most of the hold down bolts on the pylon feet carrying 2 by 220KV circuits to the north of Auckland



Bridge Mishap Brief

Scenario:
Large Cruise ship docking in the channel.
Small boat mishap and people in water close to the rear of the cruise ship.
Ship engines shut down.
Sudden large wind squall.
Cruise ship blown up harbour and “bumped” Bridge at the edge of the central span.
Some small horizontal displacement.

After inspection:

Engineers will not certify bridge as safe (liability issue)

Task

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The Prime Minister has requested your group provide a solution

Problem?

Major impact on Auckland Economy
Major impact on New Zealand economy
Major impact on many Aucklanders
Major impact on the far North
Other

This was the System's week problem from a few years back

Other Access

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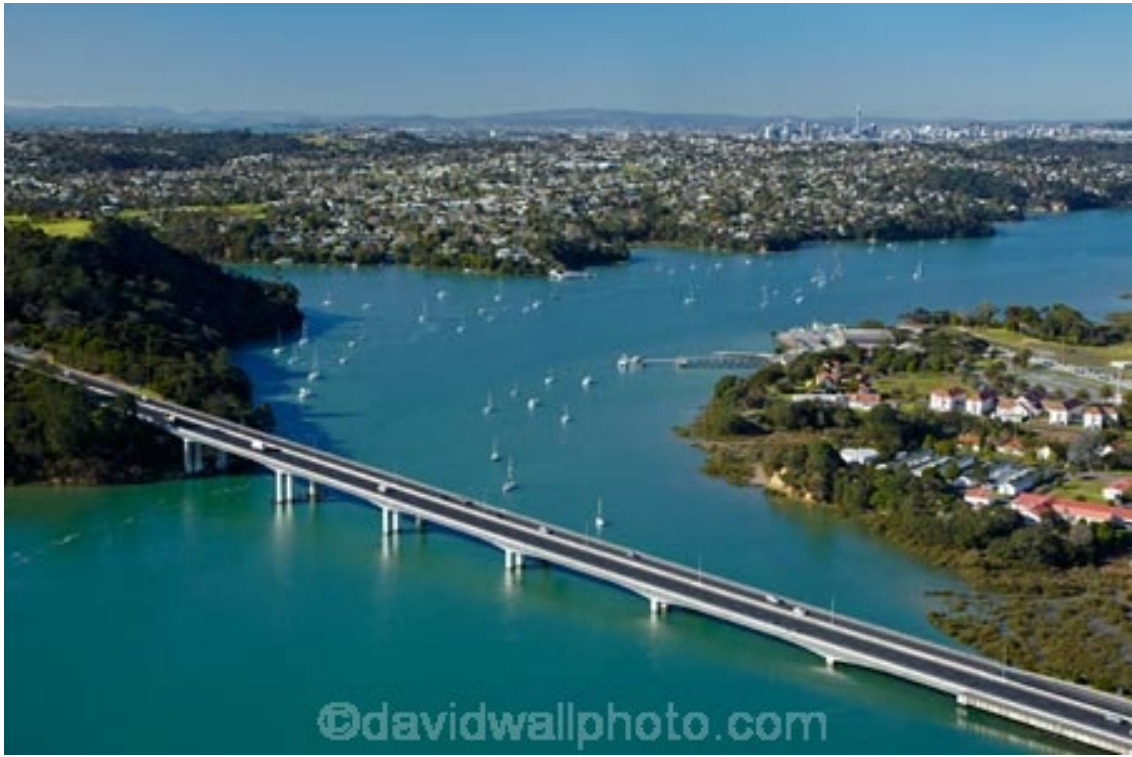
Upper Harbour Bridge – 2 lanes in each direction
Riverhead Road 1 lane in either direction (windy and slow)
14 lanes across the harbour reduced to <6



Stakeholders

Almost everyone in NZ {there will be a large impact on NZ's GDP}
Major impact on those who use the Bridge daily
Goods and services movement to and from the far north???

Action required

What are the Stakeholder's Requirements?

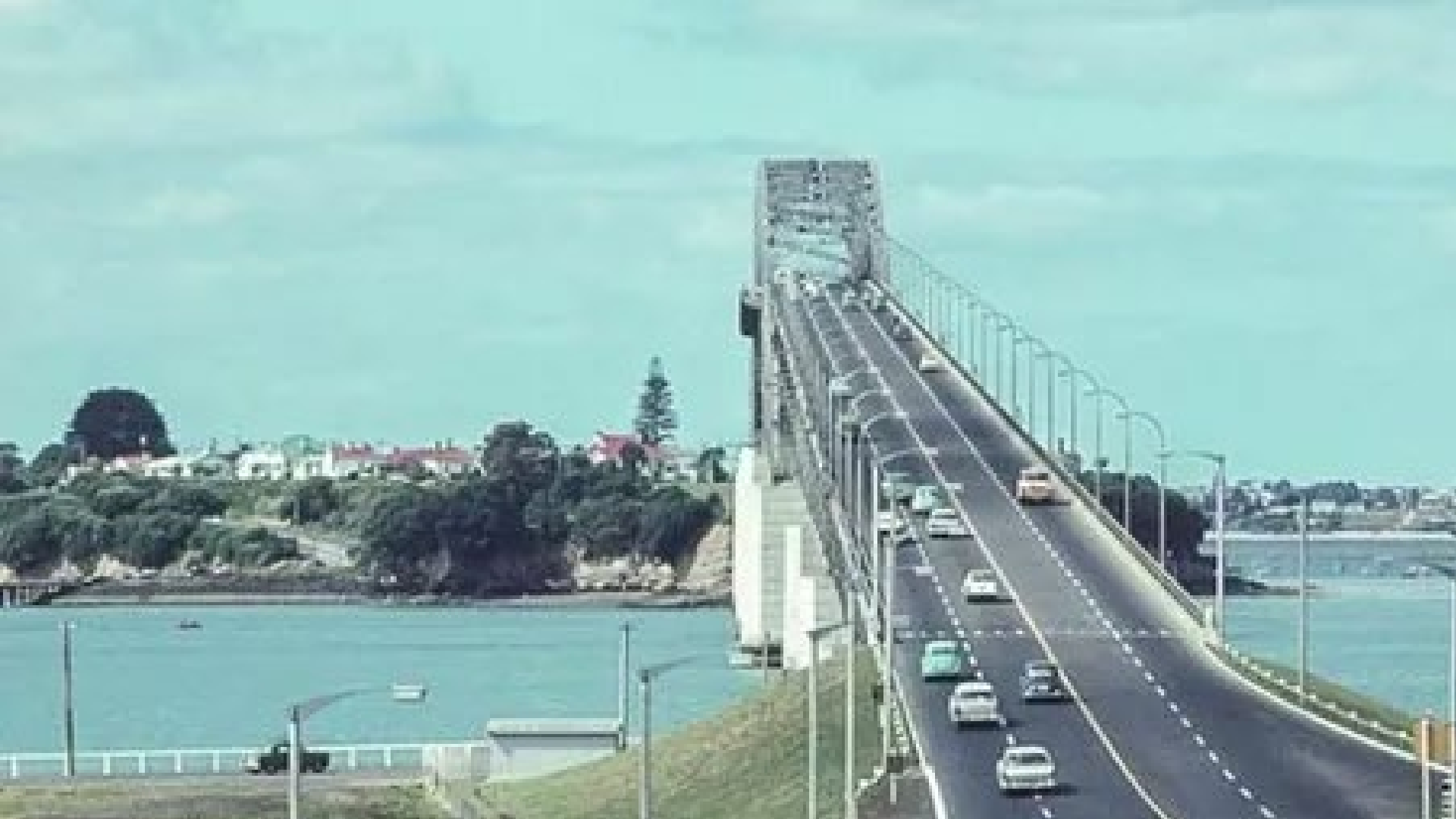
Manage/survive the next few weeks
Manage/survive the next few months
Fix or replace the bridge
Minimise impact on Auckland's economy

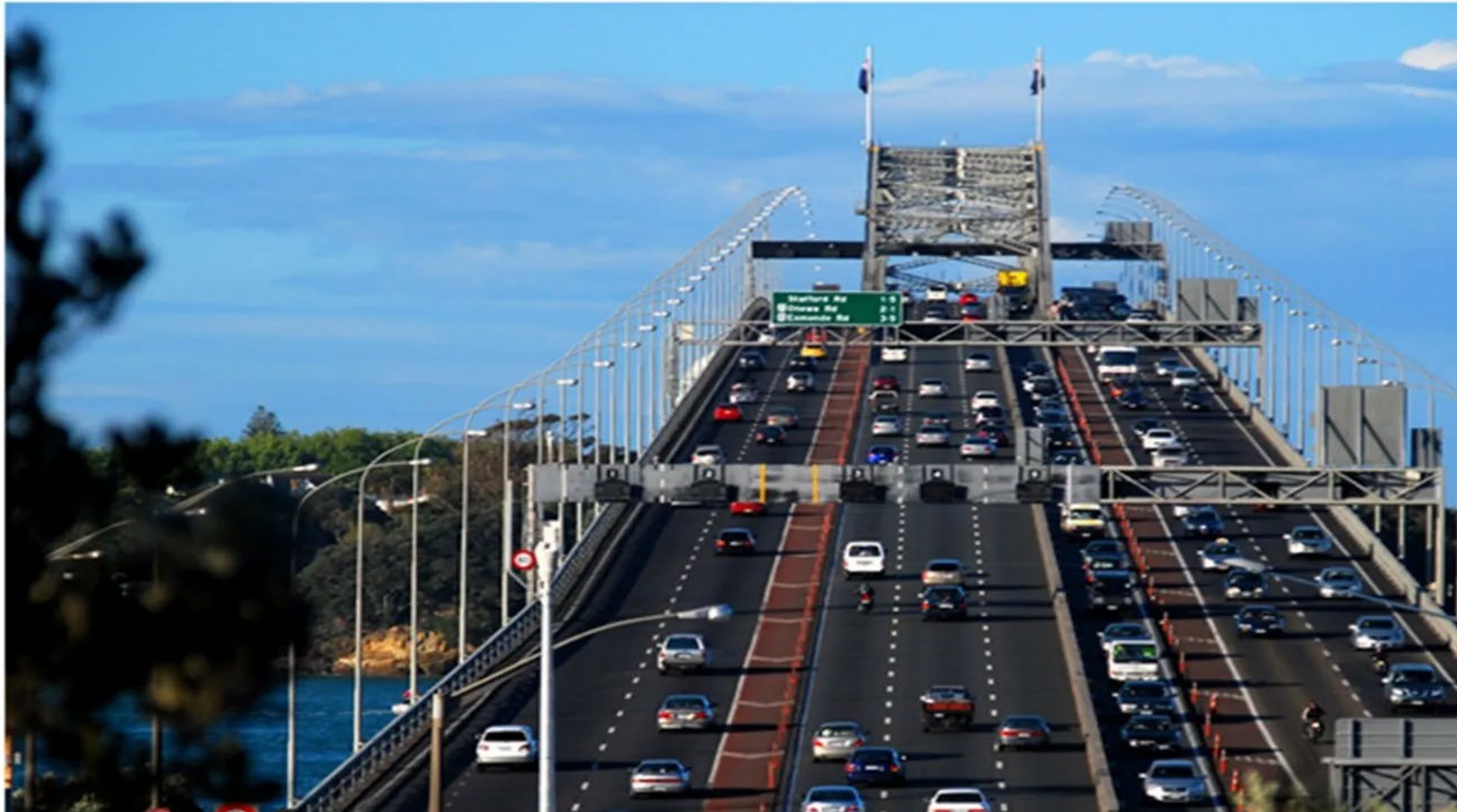
Options

Ferries, hot air ballons, buses, cable way
No trains to North Shore
Temporary accommodation near work
Accept liability and use the damaged bridge
Fix but complex
New bridge or tunnel will take many years and cost ~ 20+ billion
Other

Design Complexity

Yes originally 2 lanes in each direction when opened in 1959
Upgraded to 4 lanes (clip-on lanes) in each direction in 1969 with tidal flow added in 1980s (5 lanes to city in morning and 5 lanes from city in evening)
Seismic issues
Old structure with box girder construction





Bridge Structural Limits

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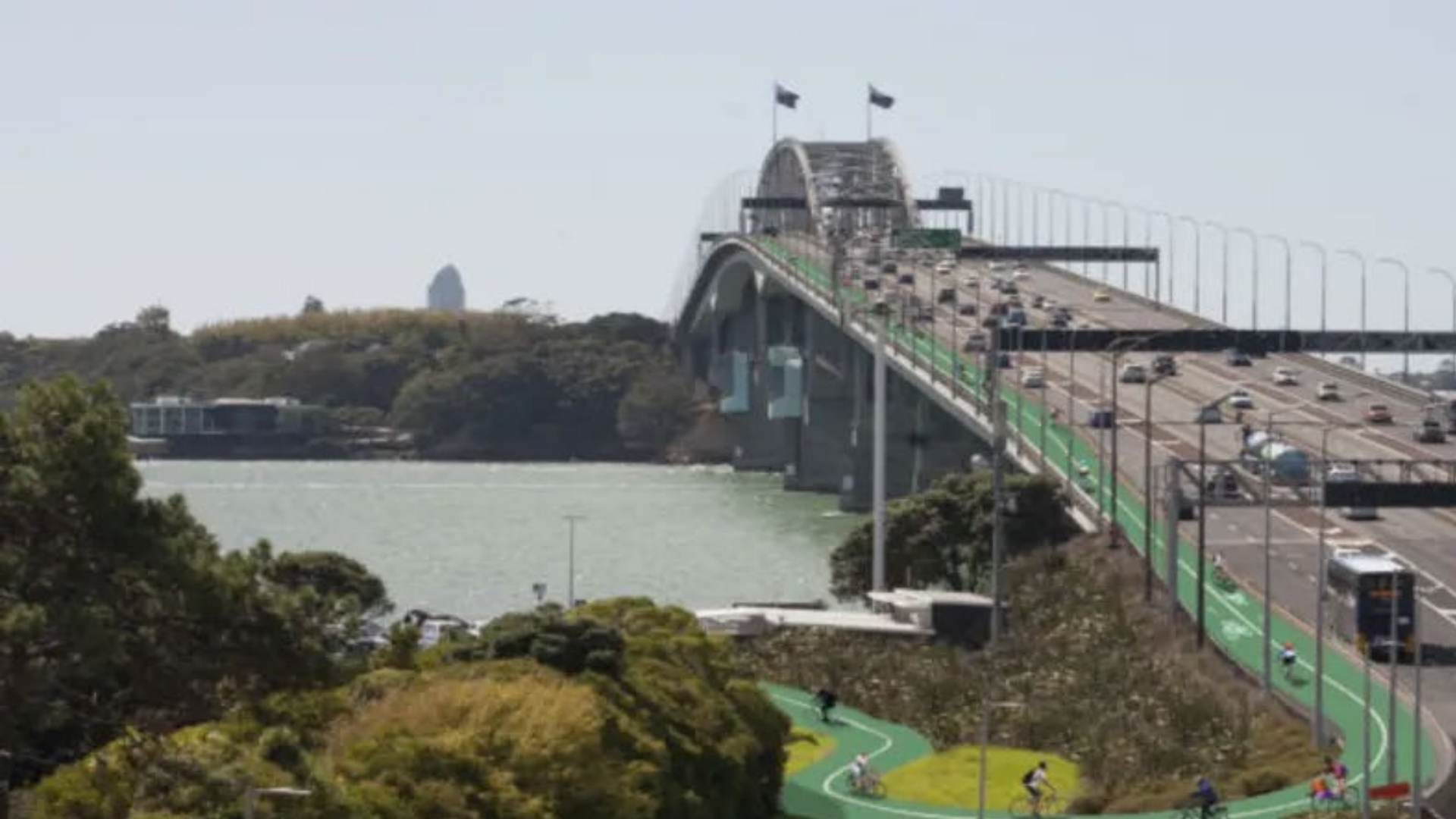
Could not add a simple cycle way on the side a few years ago



Government

Could decide Bridge is safe and assume liability of a subsequent collapse.
Health vs Wealth trade-off
Would need to override WorkSafe regulations
Not feasible without different “more recognised” expert opinion
Liability associated with a new expert opinion

Linear Sequential

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Absolutely not

This is a Systems Problem {Hairy Problem} which will require a significant Iteration of Options to determine the Best Fit with Stakeholders and their Requirements.

Best fit will be expensive and slow and will probably be the “Least Worst” answer

Parallel Workstreams

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How to survive the next few weeks?
We can not have a free for all
What are the new rules?
What 6 month plan?
What 10 year plan?

Workstreams interact

Can the Bridge be repaired?
Is this temporary or permanent?
Should a new crossing be a tunnel or bridge?
What are the “Climate” requirements of a new bridge?

Reading/Research

How many vehicles can flow in 1 lane and why?
The 2 second rule
More vehicles less speed until complete stop

About 170,000 vehicles cross the bridge each day (as of 2019), including over 1,000 buses, which carry 38% of all people crossing during the morning peak.

Why Bridge required?

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Shipping access to Chelsea Sugar Works in upper Harbour.
Yachts using the upper harbour.

Outside the Box

Build a causeway
Supply the sugar works by slurry pipeline
Upper Harbour mainly shallow

Import refined sugar

Student Solutions

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Pinch point would be the upper Harbour Bridge
Buses only on the Upper Harbour Bridge
Parking on either side of the Upper Harbour Bridge????
Use of the rail system at Henderson to get to the city
Increase capacity of the NW motorway
Try to fix the existing bridge
Build a new crossing in parallel
Tunnel???

Changes with time

Covid
What has this taught us?
We can do reasonably ok working from home
Did many consider WFH as a major answer to our Bridge problem? Some

It is difficult to think outside the box until we have no other choice.

Systems Thinking

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This was a Systems Thinking problem not a Systems Engineering problem. Something needs to be done now.
The new Bridge piece of the solution has elements of Systems Engineering

Future Brief (not 2024)

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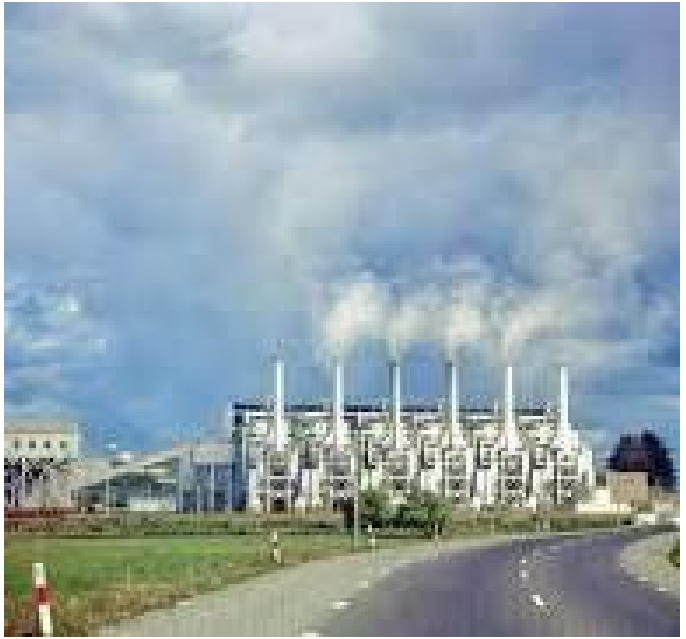
Should New Zealand commit to 100% renewable electric power?
Simple answer yes; good for Climate.
Economic answer: maybe but cost?
Need to understand our power system

Power supply must equal demand precisely at all times to keep frequency at 50 Hz.

Demand > Supply causes blackouts

History of NZ Power

- 100% hydro but vulnerable to weather
- Coal capacity added at Meremere (180MW in 60s but now gone)
- Geothermal capacity a Wairakei 70s
- Gas/Coal capacity at Huntly mid 80s 4 by 250MW units (90km south of Auckland)
- Wind and solar added recently.
- Some gas peakers.
- System originally operated by Government, now Government 50%



Meremere

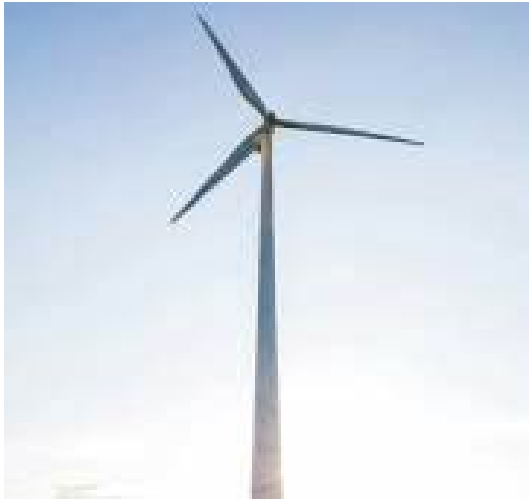
Capacitance

System has only minor hydro capacitance mainly Lake Pukaki in the South Island. Locals do not like varying Lake levels so level is tightly controlled and only modest variation.

NZ usage 43,000 GWhr (5000MW avg, 7000MW+ highs, 4000MW- lows)
Capacitance 3000 Gwhr max – less than 10%
Capacitance low at end of winter; and builds up in spring with snow melt in Southern Alps.

Climate Change

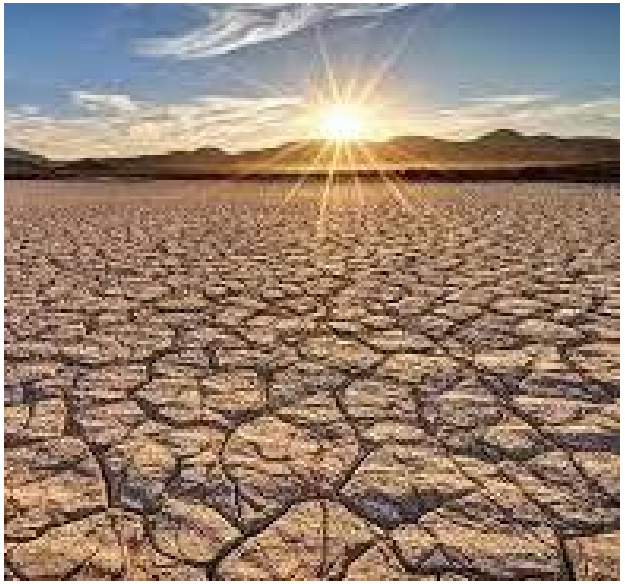
Strongly driven to close Huntly which runs on coal.
However Huntly coal stockpile represents capacitance in the system (coal can be stored outside for years).
Gas flexibility not readily available for the gas peakers
Prefer to close gas turbine plants for Climate reasons
More wind and solar???
However sun does not always shine (especially at night) and the wind does not always blow.
Geothermal stations run as base load at full capacity.
Climate impact on future weather???



2 problems

#1. Managing frequency in short term by having enough generation to meet demand (daily changes in demand: morning and evening peak; cooking, showers, heating and air conditioning)

#2. Long term > managing dry year events



Potential solutions

Overbuild generation to have standby generation available at all times. Hydro is ideal for the short time role but water may not be available if water capacitance low and required for possible future dry year support.

Standby plants do not receive revenue when in standby mode (energy only market) so must expect high prices when called to run to pay for capital.

Huntly coal is ideal for dry year. Huntly running at 500 MW for 100 days restores 50% of our water capacitance but CO2 emissions.

Conflict between goals

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Using Huntly for dry year support produces CO2.

Batteries are being installed but are tiny compared to water storage ~100+ MWhr (100MW for 1 hour or 50MW for 2 hours).

Add more water storage. Lake Onslow considered but too expensive

Climate vs Cost of Living

Power: Right/Privilege

If there are power blackouts do we accept this as required to meet our Climate obligations **or do we got nuts as no internet.**

The problem of resilience of our power system is easily resolved if power prices increase.

However the cost of living is already a major issue

Systems Thinking

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Stakeholders and Requirements

- Government wants lower power prices and 100% reliability both in the short and long term with no CO2 emissions.
- Power companies: want to remain financially viable.
- Population: want fair pricing and may (???) accept a few hours per year without power.
- Power mainly seen as a “right” in NZ

Options

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- Retain Huntly for dry weather. {Will dry conditions be more or less common with increasing Climate Change?}
- Change the market structure to pay the capital charge for standby generation capacity.
- Build lots of batteries around the country?? (as a first approximation 10,000 batteries would be equivalent to Huntly).
- Add nuke generation capacity?? (no CO2 but other issues).
- Compromise: coal usage only in dire circumstances and have system pay for the ongoing maintenance of Huntly to keep the station ready to generate.
- **Hope for the best**
- **Other**

Iteration & Least Worst

What is the rest of the world doing on Climate?

How to balance Climate Issues vs Power Reliability vs Power Cost vs Stakeholder Requirements.

Probably no good answer.

Different Systems Brief

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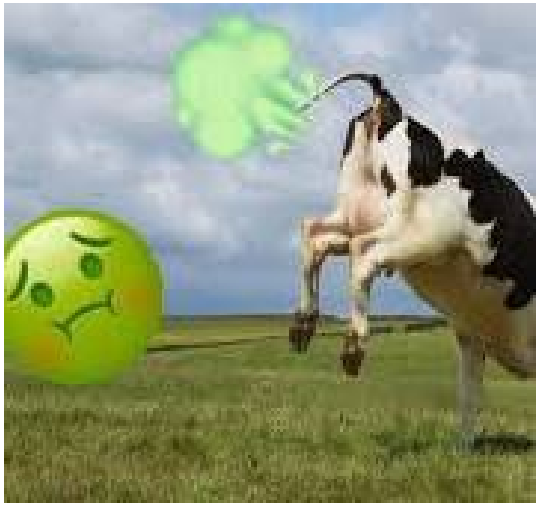
NZ great location for growing grass
Cows superb to convert grass into food/protein
Dairy is a big earner for the NZ Economy
NZ can feed 100 plus million people
Cows produce methane; 25 times impact of CO2
NZ committed to Paris 2050
Ban cows >>> major farming and economy impact
NZ an efficient dairy producer



Trial a major switch from agriculture to horticulture

Engineering Curriculum

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This was another System's Week Brief from the past

Who should we consult?
Our most recent customers? That means this 4th year graduating class in a few months
Should we just look at Auckland, or Engineering degrees across NZ?
Should we just look at Engineering or all degrees?
Should we just look at Degrees or also all Universities in NZ?

First Systems Brief

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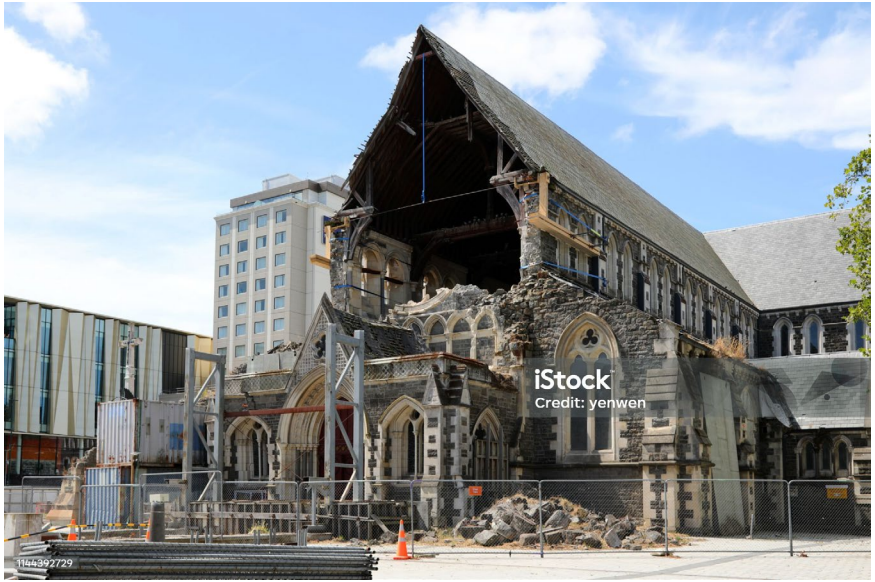
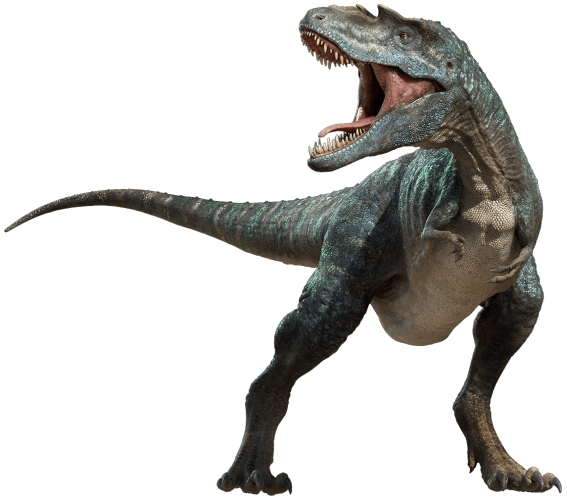
How to fix Christchurch after the earthquake in 2011

In my personal opinion the Student's proposed solution were superior to what has been done (and is still being done) to fix Christchurch



About myself

Rob Kirkpatrick (old dinosaur) Adjunct Professor
Graduated from this Faculty in ‘72 BE 1st
PhD Manchester UK in ‘75
Worked in global Refining and Petrochemicals for 30 years.
Singapore Refinery Technical, Ops and Project Manager,
Director of Technology Methanex, GM of Motunui,
Geothermal Board member.
Involved with System since 2011
Written all the System’s Briefs up until recently



Final Word

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Generic feedback: most students are glad they survived Systems Week, never want to repeat the experience, but will remember the learnings forever.

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