National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

infrastructure

RNC/QuakeCoRE Distributed Infrastructure

11th June 2018

Criticality assessment and Asset health management of electricity infrastructure components factoring resilience

Draft Research Slides For Developing New Asset/Lifeline Criticality Framework

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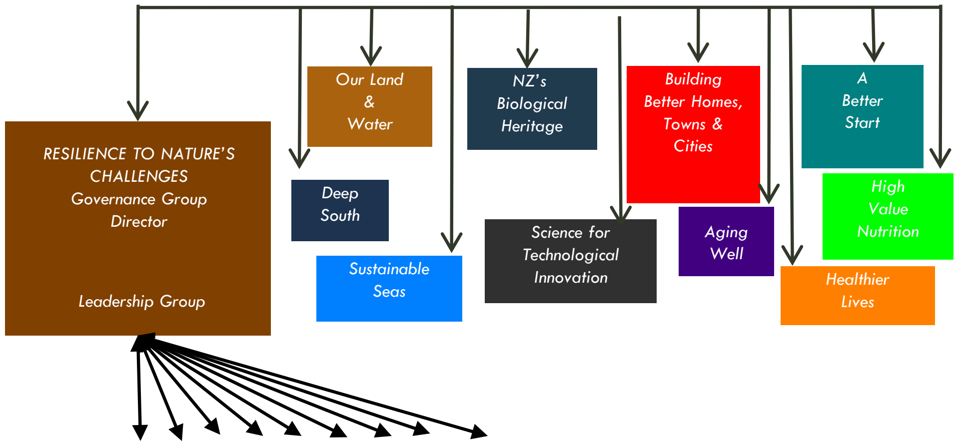
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Outline

- Introduction to RNC Project
- Electricity – Communication Lifeline Infrastructure Resilience
- Introduction
  - Electricity Asset Management
  - Incorporate Asset Management to Resilience Framework
  - Asset Health Management
  - Criticality Assessment
- Case Study on Electricity Asset management
- Research Questions
- Approach
- Ongoing Activity
- References
- Q&A

Ministry for business, innovation and employment national science challenges

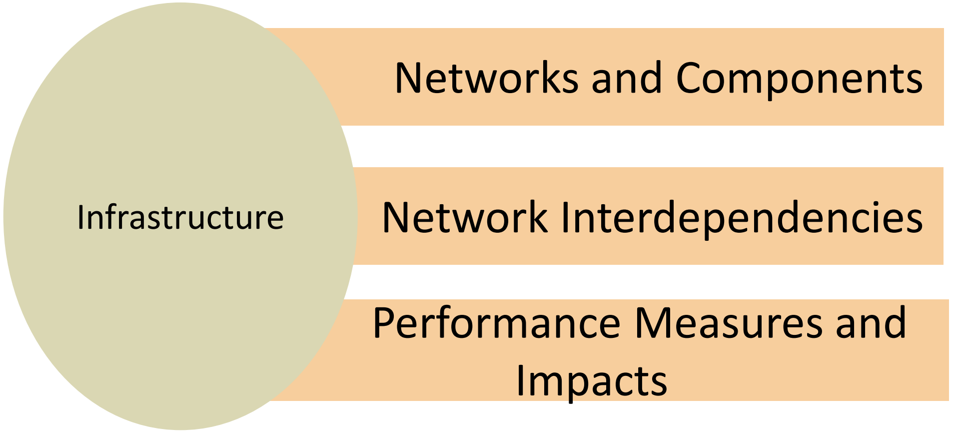


Contractual research funding relationship *between* MBIE (contractor) *and* The research provider (research institutions) through GNS Science – RNC host (hosts the RNC director)

Sub-contractual research funding relationships

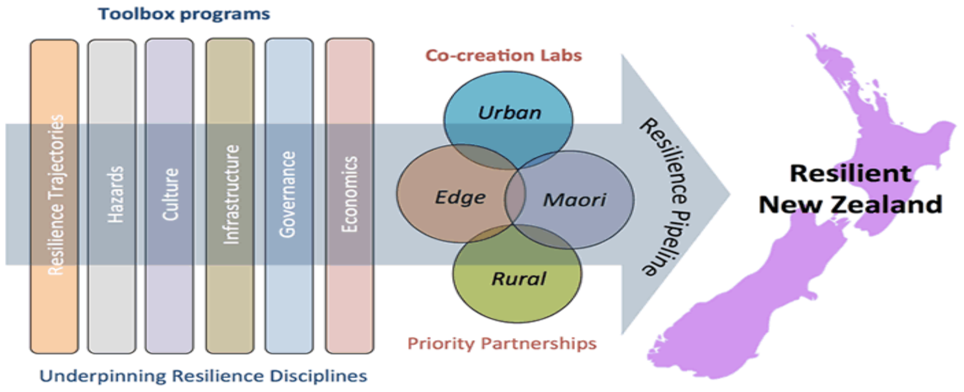
GNS (contractor) & lead research institutions;
⇅
Lead research institutions & Program members (research institutions)
⇅
Program members (research institutions) & researchers

RNC 1 Goals



Reference [10]

2015-19 Research Program – Resilience to Nature's Challenges



Reference [7]

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

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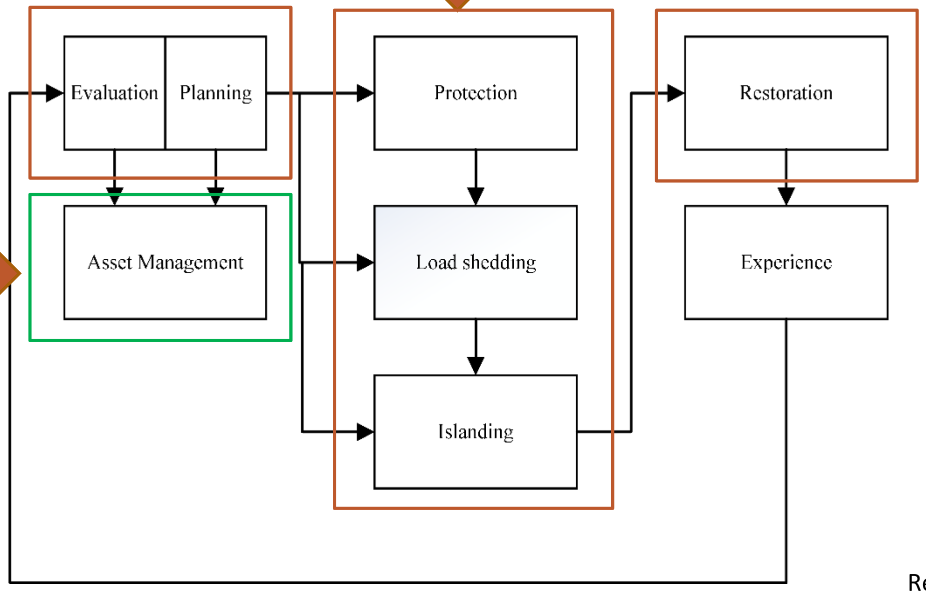
Electricity- Communication Lifeline Infrastructure Resilience

infrastructure

Electricity Distribution Resilience Framework through West Coast Alpine Fault Scenario

Nirmal Nair (PI), Andrew Austin (AI), Farrukh Latif (ME, Chorus), Samad Shirzadi (PhD), Duncan Maina (PhD), Yang Liu (Postdoc), Daniel Blake (Postdoc), Liam Wotherspoon (RNC DI, Lead)

Ebad Ur Rehman (PhD)



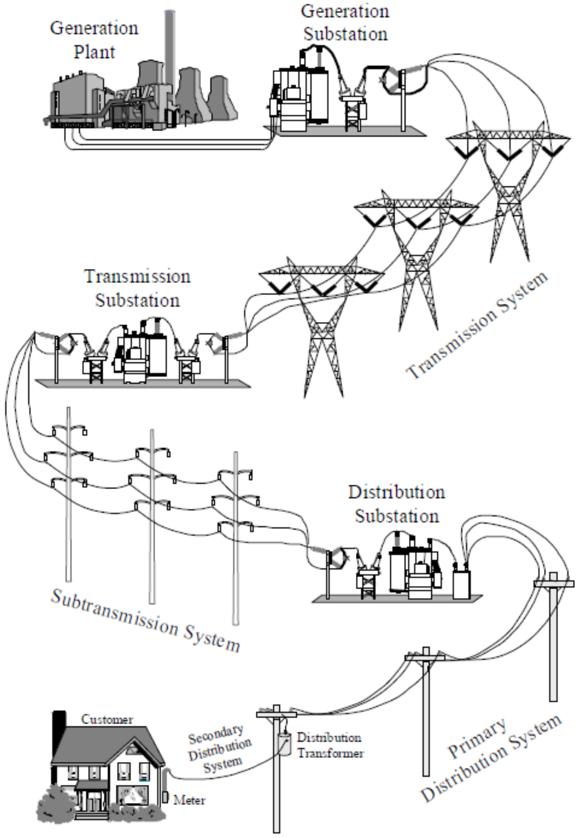
Reference [7]

"Electricity Network Assessment during Alpine Fault Event: microgrid as a solution for restoration" (Samad Shirzadi Deh Kohneh)

"Disaster related recovery of power networks" (Duncan Maina)

"Electric Power Distribution Systems Resilience Modelling Toolbox" (Leo Liu)

Electricity Asset Management



Reference [7]

Risk Mitigation

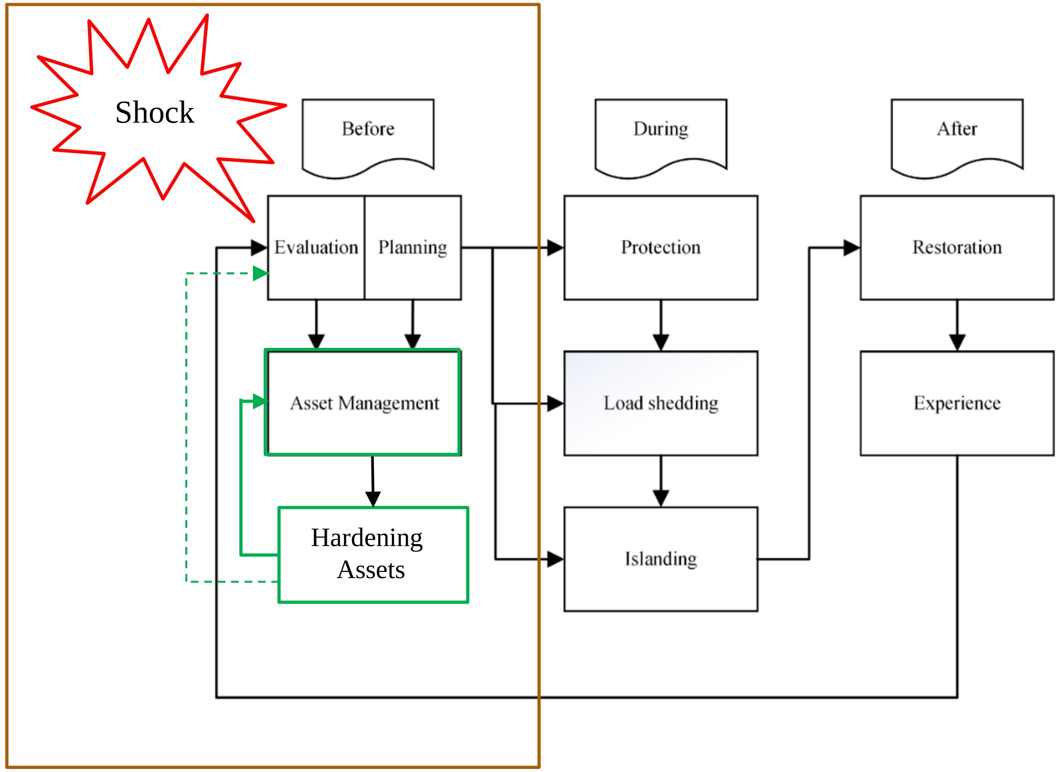
Balancing Trade-offs

Performance Improvement

Cost Reduction

- Improve system reliability
- Satisfying stakeholders and customers

Incorporating Asset Management to Resilience Framework



Resilience in Power Systems (Electricity)

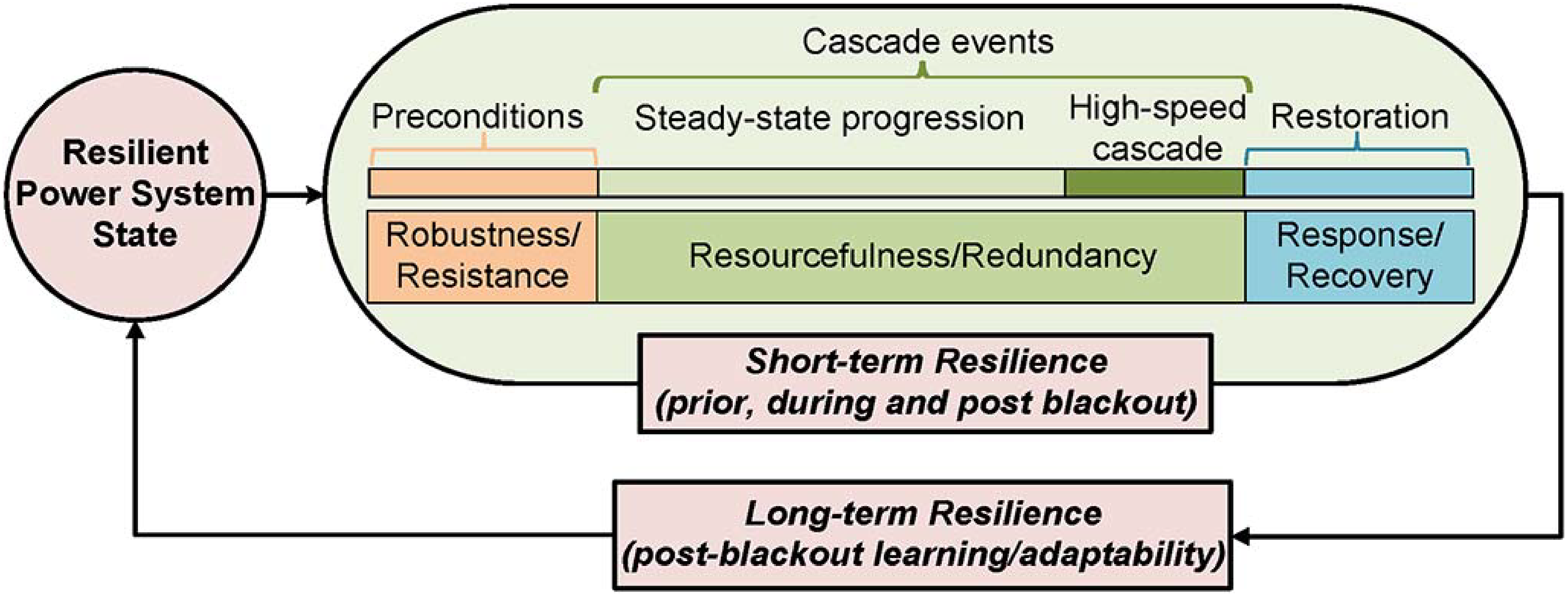
Ability of a Power System to withstand extraordinary and high impact-low probability events

Key Features:

Robustness	• Keep operating or stay standing in the face of disaster • Withstand low-probability but high-consequence events
Resourcefulness	• Effectively manage a disaster as it unfolds • Identify options, prioritize what should be to control and mitigate the damage
Rapid Recovery	• Get things back to normal as fast as possible after a disaster • Contingency plans and emergency operations
Adaptability	• Absorb new lessons from a catastrophe • Introduce of new tools and technologies for boosting robustness, resourcefulness and recovery before the next crisis

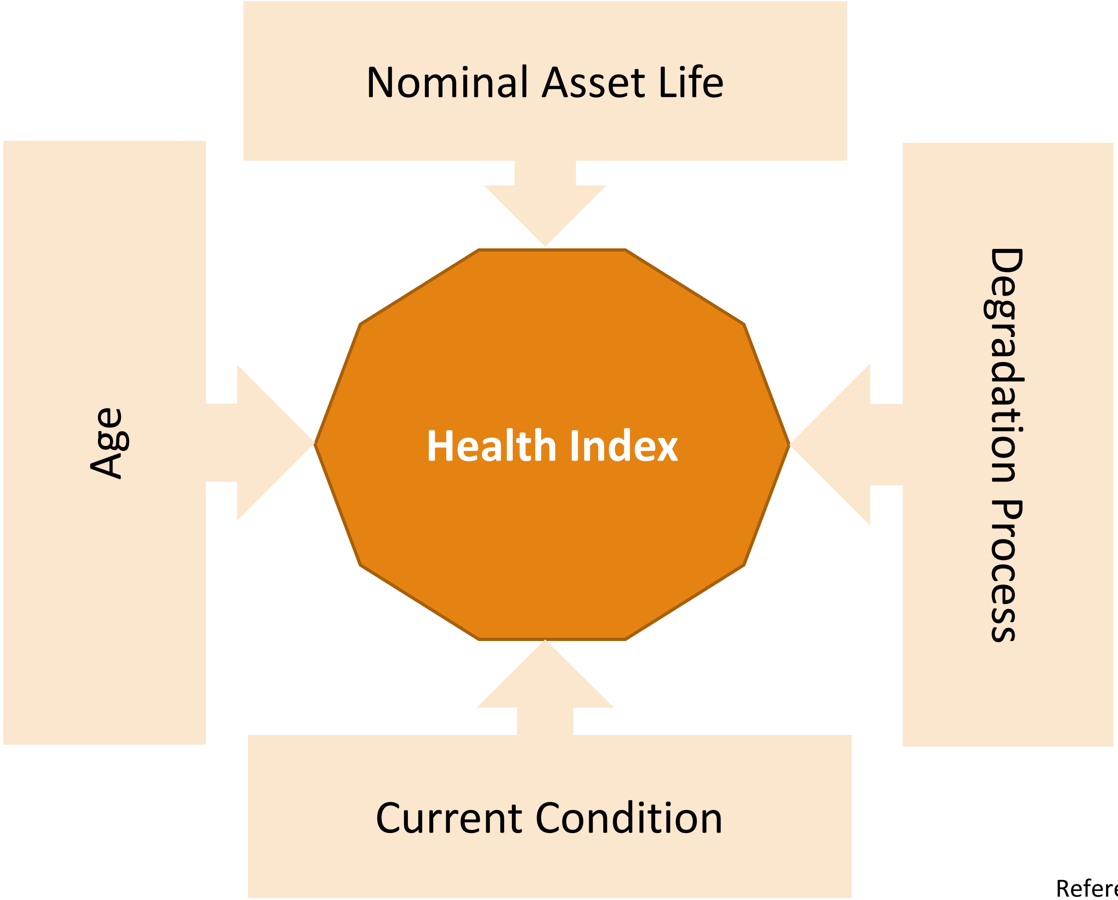
Reference [2]

Power System's "Short" and "Long" term resilience



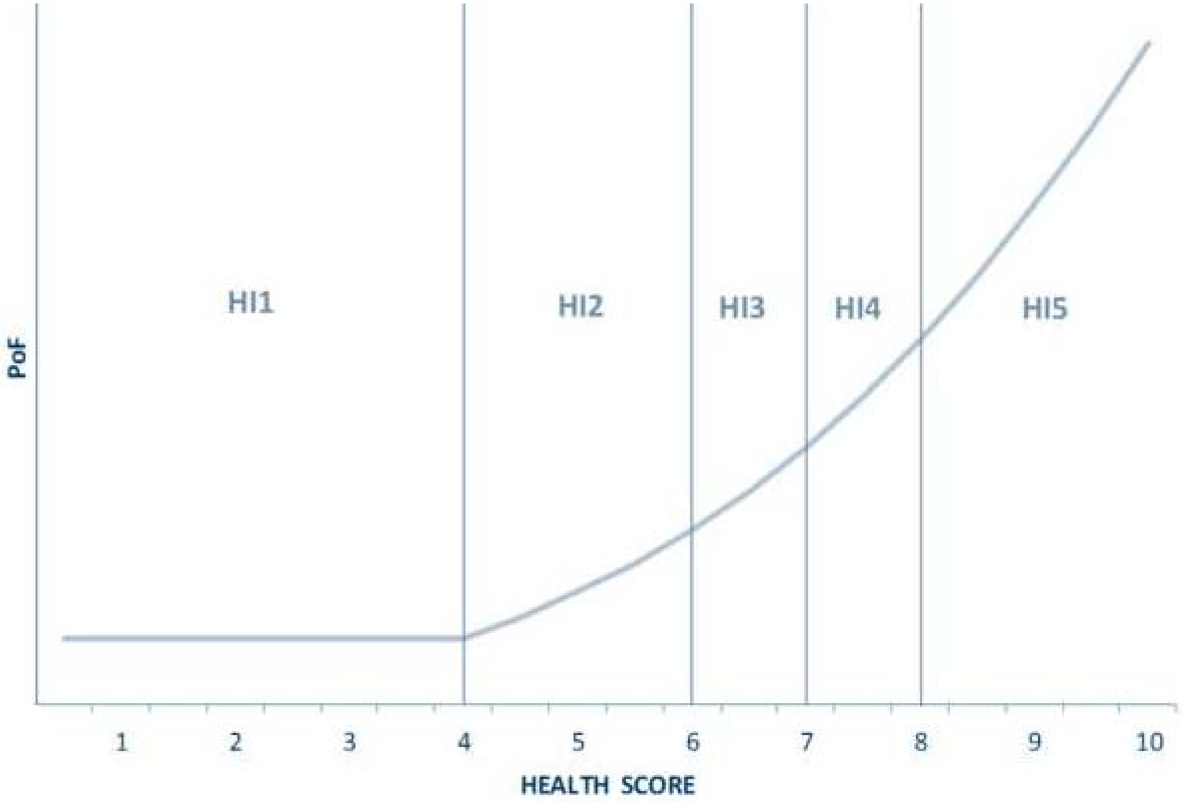
Reference [2]

Asset Health Management



Reference [8]

Health Index Score and Range



Reference [4]

HI1	New or as new
HI2	Good or serviceable condition
HI3	Deterioration, requires assessment or monitoring
HI4	Material deterioration, intervention requires consideration
HI5	End of serviceable life, intervention required

Reference [4]

$$PoF = k \cdot \left(1 + HI \cdot c + \frac{(HI \cdot c)^2}{2!} + \frac{(HI \cdot c)^3}{3!}\right)$$

where:

PoF = probability of failure per annum

HI = health index

k & c = constants

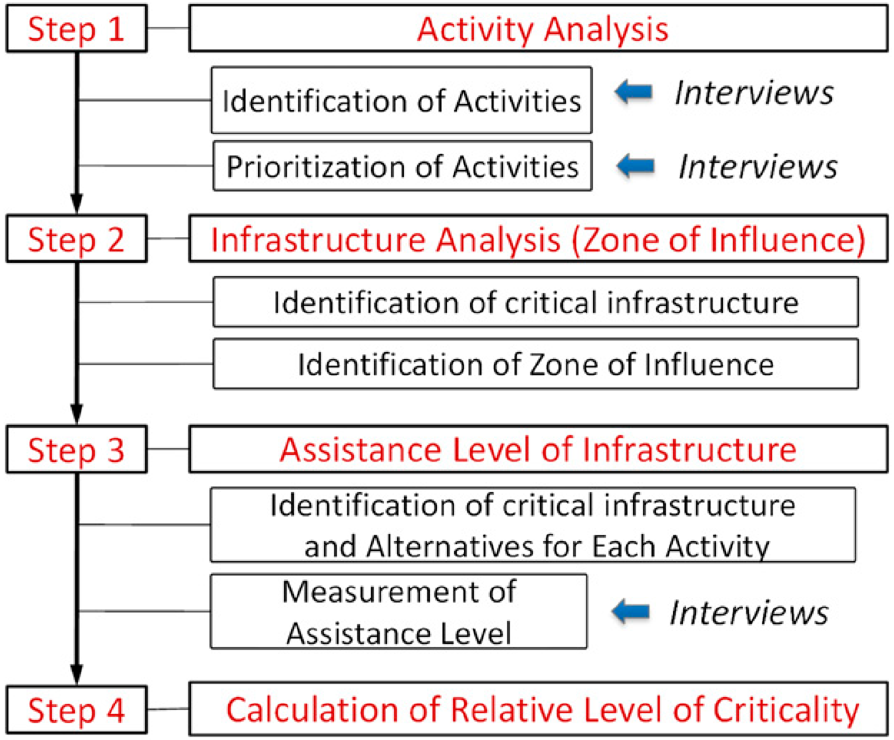
Reference [8]

Lifeline Criticality Assessment

Criticality is the measure of the consequences of asset failure

Criticality is rated in the following categories:

- ❑ Network Performance
- ❑ Safety
- ❑ Environmental
- ❑ Financial



Reference [3]

Criticality Index

C1	Low Criticality	0% to 75% of Avg
C2	Average Criticality	75% to 125% of Avg
C3	High Criticality	125% to 200% of Avg
C4	Very High Criticality	>200% of Avg

Reference [4]

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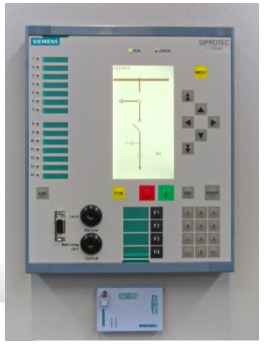
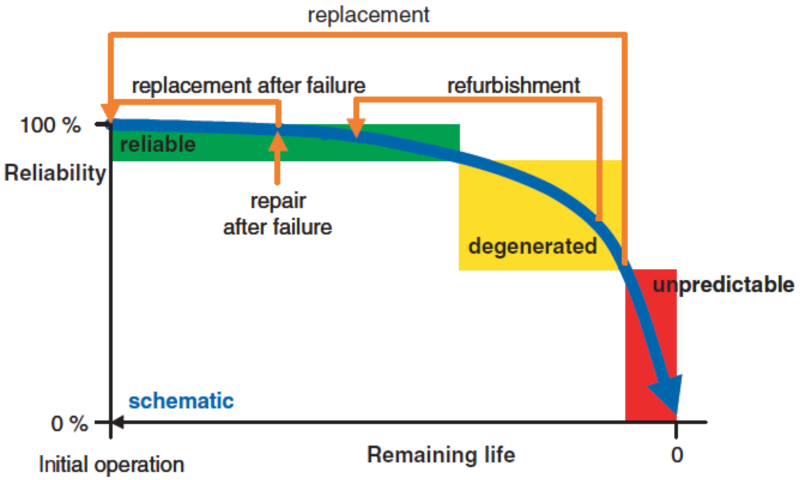
Case Study on Electricity Asset Management

- **Primary Equipment's**
  - Transformers
  - Switchgear
    - Circuit Breakers
    - Reclosers
  - Transmission and Distribution
    - Overhead lines
    - Poles
    - Underground cables
    - Substation Busbars
- **Secondary Equipment's**
  - Protective Relays
  - Communication Devices
  - Backup Batteries
  - Others

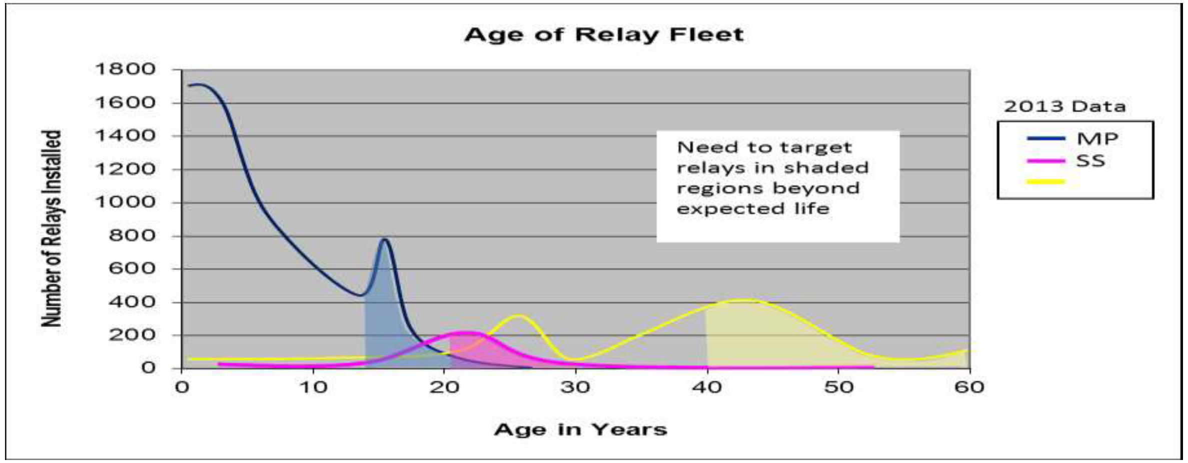




Reference [1]

Case study on Relays

RELAY ASSET 2015 YEAR END	Number In Service	Average Age	Median Age	Standard Deviation
Microprocessor	19,379	7.5	5	6
Solid State	2,935	20	20.5	9
Electromechanical	12,763	41	41	18
TOTAL	35,077			



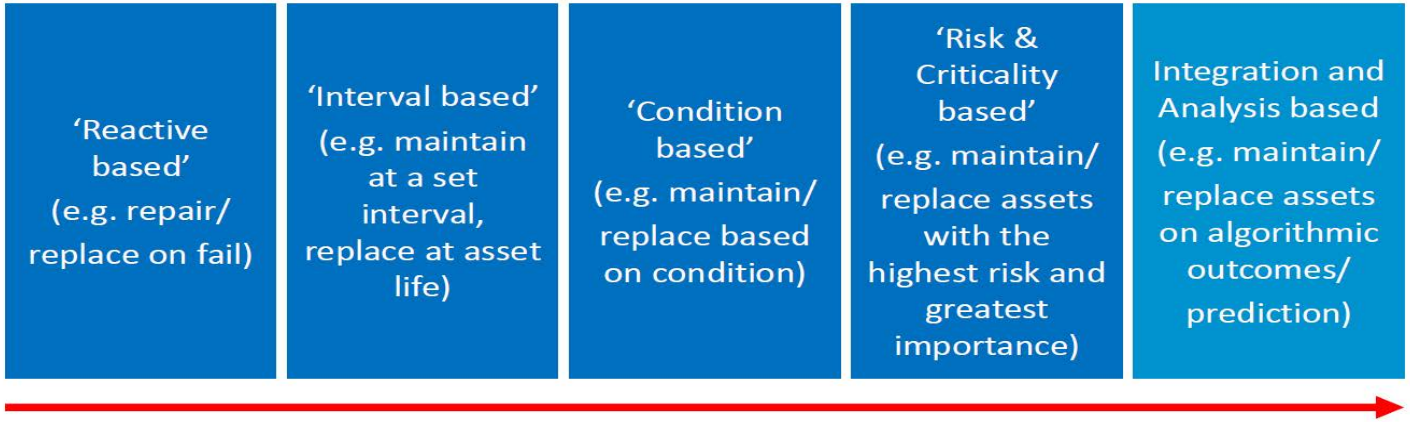
Reference [6]

Goal and Approach

Approach

- Conduct Tests
  1. Partial discharge
  2. Ductor reading
  3. Insulation resistance
  4. Tan-Delta

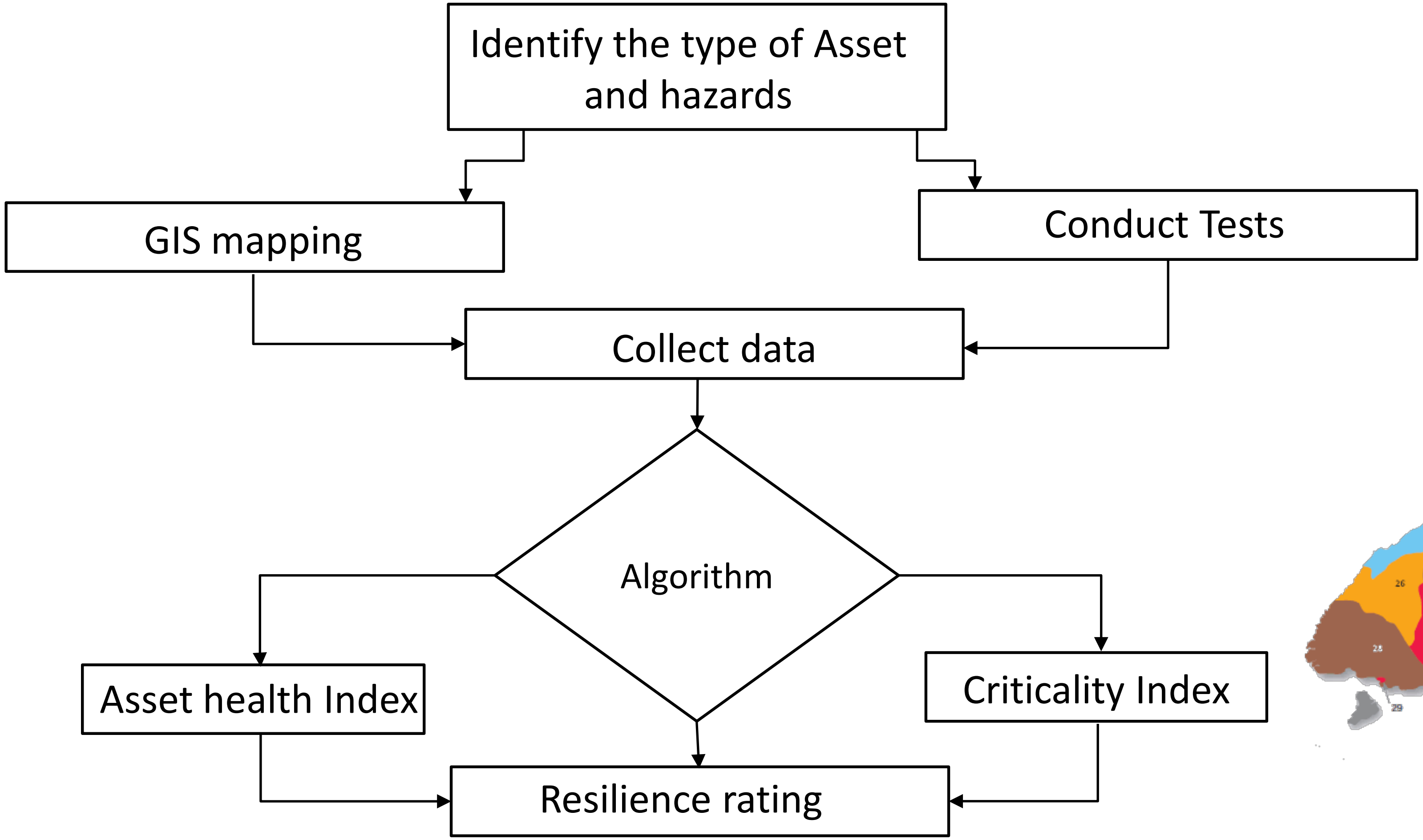
- Asset management framework

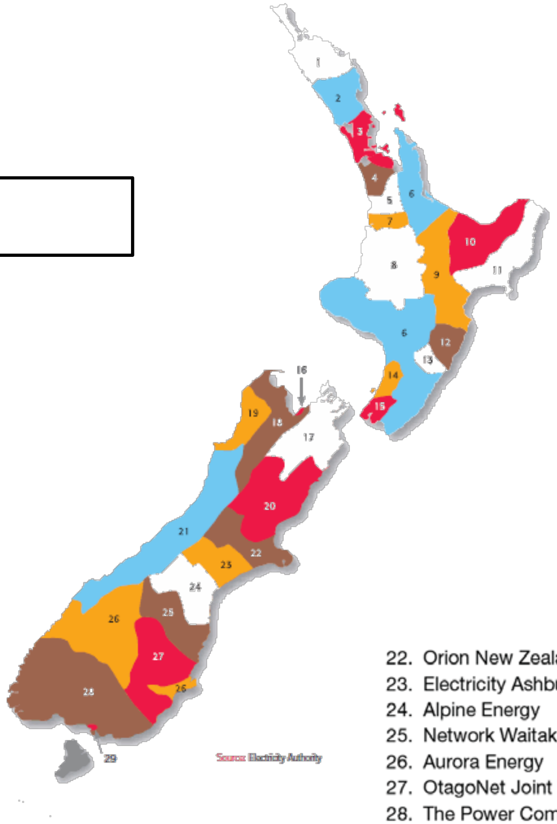


Develop an "infrastructure resilience rating" system in the longer term indicating resilience to natural hazards of the infrastructure serving a community. This rating system will help drive public policy in infrastructure investment and provide building owners with knowledge of externalities when investing in building resilience.

Reference[5]

Approach





1. Top Energy
2. Northpower
3. Vector
4. Counties Power
5. WEL Networks
6. Powerco
7. Waipa Networks
8. The Lines Company
9. Unison Networks
10. Horizon Energy Distribution
11. Eastland Network
12. Centralines
13. Scanpower
14. Electra
15. Wellington Electricity
16. Nelson Electricity
17. Malborough Lines
18. Network Tasman
19. Buller Electricity
20. Mainpower New Zealand
21. Westpower
22. Orion New Zealand
23. Electricity Ashburton
24. Alpine Energy
25. Network Waitaki
26. Aurora Energy
27. OtagoNet Joint Venture
28. The Power Company
29. Electricity Invercargill

[7]

Research Questions

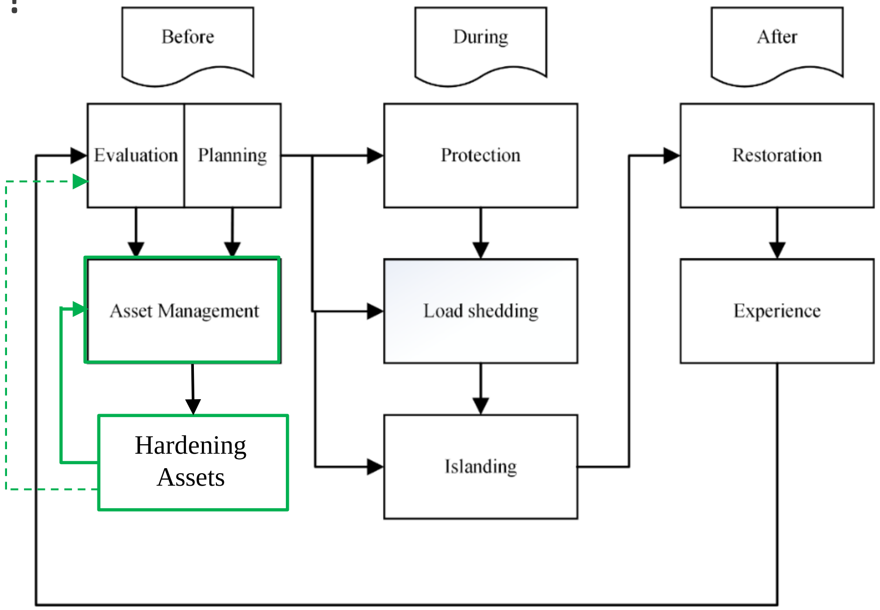
A. What is the life cycle distribution of electricity assets?

B. How to relate the asset management, criticality and infrastructure resilience rating?

C. What role do you see the asset health index guide playing in the future?

D. How will a specific investment profile affect the asset's health?

E. How to strengthen the current power system assets?



Ongoing Activities

- Studying the health and lifeline of underground cables effected by Canterbury earthquake.
- Mapping the data with GIS maps to improve resilience during such events.
- Plot fragility curves to determine the damaged caused by earthquake events.
- Does the infrastructure resilience rating depend upon the type of shock.
- Assess the age and criticality of the assets.

	Airport	Broadcasting	Electricity	Fuel	Gas	Ports	Rail	Roads	Telecomms	Wastewater	Water Supply	Comments
Airport		3	2	2	3	3	3	1	3	2	2	Dunedin Airport self sufficient 3-4 days with backup generators for terminal building and control tower plus 500,000l water, and on site wastewater treatment/disposal. Fuel critical but 3-4 days storage and larger aircraft could refuel at destination airports. Road access critical but airport serviced from 3 directions providing alternates if one closed.
Broadcasting	3	0	2	3	3	3	3	2	3	3	3	Mt Cargill Transmission Facility is self sufficient for generators / fuel for 20 + day.
Electricity	3	3	1	2	3	3	3	2	2	3	3	Distributors and generators rely on Transpower network being operational. Fuel, roads and telecomms become more critical (1) in coordinating and emergency response situation.
Fuel	3	3	1	1	3	1	3	1	2	3	2	Can gravity feed or use air compressors/pumps to supply from terminals (could also be used at fuel stations but would be unmetered supply) if electricity failure. Water required at flammable sites (petrol) but self contained water supplies now required. All fuel comes in via ship and distributed via roads.
Gas	3	3	2	3	3	1	2	1	2	3	1	Gas comes in via rail and port and is distributed by pipe and road - Fryatt Street is the main road to and from the terminal. Water supply required for fire fighting, though alternatives are sea water pump (if electricity operating) or fire service appliance (if available).
Ports	3	3	1	2	3	0	1	1	2	3	2	Electricity backup on for emergency functions, > 24 hours would have significant impact on operations. 2/3 of cargo is transported to / from the port by rail, the rest by road. Road also required for staff access. Fuel required for ship bunkering. Water supply required for staff but could bring in.
Rail	3	3	2	1	3	3	0	1	3	3	3	Roads critical for transfer of freight and passengers. Electricity critical for network control. Fuel required to operate trains.
Roads	3	3	3	3	3	3	3	1	3	3	3	Main dependency is between NZTA and local road authorities. While traffic lights require electricity, manual traffic management can occur and in other places traffic should revert to normal road rules.
Telecomms	3	3	2	3	3	3	3	2	1	3	3	Require electricity but main sites have generator backup while smaller sites have battery backup that can operate 4-60 hours. Telecommunications network is highly interconnected meaning many telcos rely on other's assets. Roads required for access to sites - more critical in emergenies.
Wastewater	3	3	1	3	3	3	3	2	2	0	2	Dunedin's main Musselburgh PS is the only sewer PS with backup generation on site. Most PS have emergency storage in dry conditions of between 2 and 8 hours and designed spill structures to discharge overflows safely to waterways. Treatment plants do not have backup generation though some biological treatment would still occur in ponds/wetlands.
Water Supply	3	3	1	3	3	3	3	2	2	3	0	Water pump stations and treatment plants do not have on site generators, relying on treated storage reservoirs (typically holding 1-3 days supply) to maintain supply until electricity restored. Reliance on telecommunications for automated control, loss of which could cause reduction in water quality.

1 = Critical for Service to Function 2 = Critical for service to function but some backup or part function. 3 = Not required for service to function. 0 = Not Applicable

Reference [11]

References

[1] – Schneider J, Gaul J. A, Neumann C, Hografer J, Wellbow W, Schwan M and Schnettler A, “Asset Management techniques”, in Electrical Power and Energy systems, Vol 28, pp 643-654, March 2006.

[2] – Panteli M and Mancarella P, “Modeling and Evaluating the Resilience of Critical Electrical Power Infrastructure to Extreme Weather Events”, in IEEE Systems Journal, Vol. 11, PP 3, September 2017.

[3] – Oh H. E, Deshmukh A and Hastak M, “ Criticality Assessment of Lifeline Infrastructure for Enhancing Disaster Response”, in Natural Hazard Review, Vol 14 (2), PP 98-107, May 2013.

[4] – Blackmore P, “Common Network Assets Indices Methodology”, EA Technology.

[5] – Brown E, “Transforming Asset Management: New Technologies, New Opportunities”, IET UK and The Energy Systems catapult.

[6] – Sykes J, “ Comprehensive Asset Strategy”, PG&E Wellington, NZ, June 2016.

[7] – Nair N, “Electricity Distribution Resilience Framework informed by West Coast Alpine Fault Scenario”, Distributed Infrastructure Toolbox: NSC-RNC Project, March 2018.

[8] – Law D, “ The Journey and Application of Risk Forecasting in Orion”, Orion, Christchurch, NZ, June 2016.

[9] - https://resiliencechallenge.nz/Resilience-Home/Science-Programmes/Infrastructure/How-can-we-keep-the-lights-on-during-and-after-a-natural-disaster.

[10] - https://resiliencechallenge.nz/Resilience-Home/Science-Programmes/Infrastructure.

[11] - Lisa Roberts, “Strategic engagement in lifelines projects EEA Asset Management Forum”, June 2016.

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