Te Hiranga Rū | QuakeCoRE
Aotearoa New Zealand Centre for Earthquake Resilience

Integrated telecommunications and electricity assessments for response to natural disasters

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Plan

Context

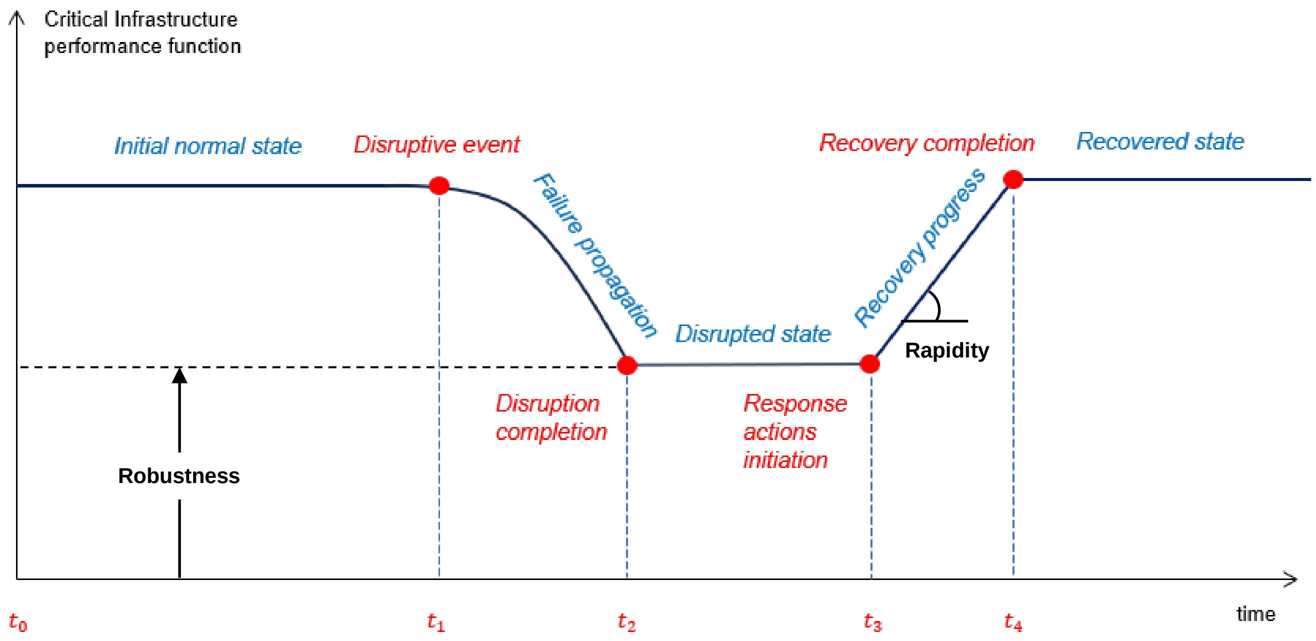
- Critical infrastructures, Emergency and Resilience
- The communication lifeline
- Quantification of resilience
- Scope

Approaches for assessments

- Geospatial and dependency analysis
- Data science approach

Critical Infrastructures, Emergency and Resilience

Resilience: ability of **withstanding** and **recovering** from disruptive events



4Rs of CI resilience: **Robustness**: ability to withstand

Redundancy: degree to which components and units are interchangeable

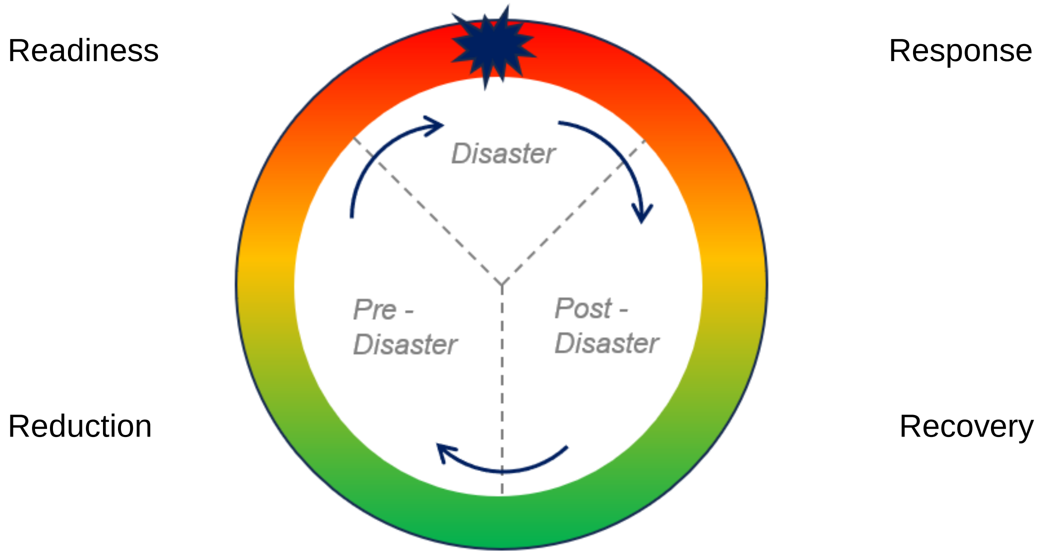
Resourcefulness: capacity of using and mobilizing resources

Rapidity: rate at which the system can recover

Critical Infrastructures, Emergency and Resilience

Resilience: ability of **withstanding** and **recovering** from disruptive events

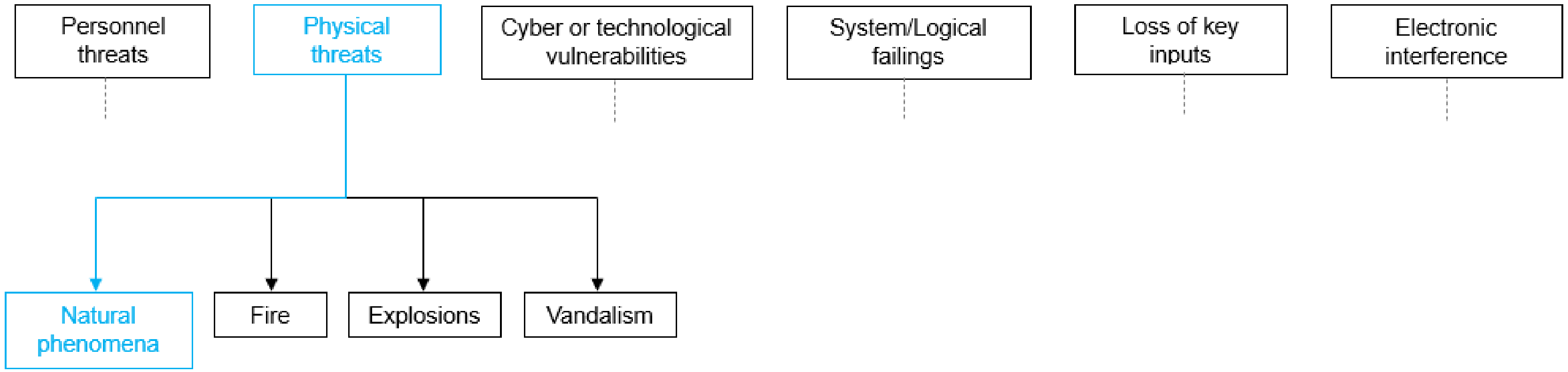
4Rs of Civil Defence: **Reduction**: identification of long-term risks and reduction of their impacts
Readiness: development of capabilities and programmes before the emergency
Response: actions taken immediately before, during or directly after an emergency
Recovery: restoration of services and regeneration of communities after an emergency



The communication lifeline

Specificities of the sector

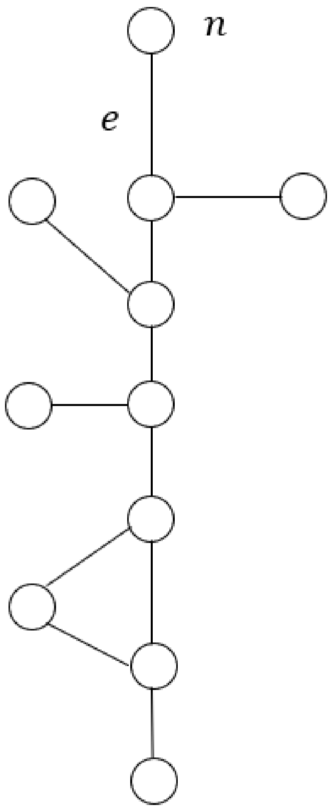
- **Diversity** of technologies
- Mostly **privately-owned**
- Standards:
  - ISO 31000: risk management
  - ISO 22301: business continuity management
  - ISO 27001: information security
- Cybersecurity and resilience



Quantification of resilience

Metrics for telecommunications networks

- **Topology**



Closeness centrality: $c_c(n) = \frac{N-1}{\Sigma_u \, d(u,n)}$, where $d(u,n)$ represents the distance between node u and node n

Node betweenness centrality: $C_B(n) = \sum_{u \neq v \neq n} \frac{\sigma_{u,v}(n)}{\sigma_{u,v}}$,

Edge-betweenness centrality: $C_B(e) = \sum_{u \neq v} \frac{\sigma_{u,v}(e)}{\sigma_{u,v}}$,

where $\sigma_{u,v}(n)$ and $\sigma_{u,v}(e)$ are the number or shorter paths from node u to node v that passes through the node n (different from u and v) and the edge e, and $\sigma_{u,v}$ the total number of possible paths between two nodes, without including the node n

Algebraic connectivity: determined via analysis of eigenvalues of the Laplacian matrix of the graph

$$L = \begin{cases} \deg(u) \quad if\ u = v \\ -1\ if\ u\ and\ v\ are\ connected \\ 0\ otherwise \end{cases}$$

Quantification of resilience

Metrics for telecommunications networks

- **Dependability** Mean time between failure: $MTBF = \frac{\sum Operational\ Times}{Number\ of\ failures}$

  Mean time to repair: $MTTR = \frac{\sum Maintenance\ \ Times}{Number\ of\ maintenance\ operations}$

- **Service delivery** Quality of Service (QoS): delay
  packet loss
  throughput

  Quality of Experience (QoE), which can be related do situational awareness

Failure modes in the face of natural disasters

Three main failure modes experienced by telecommunications networks

- **Traffic congestion**: usually observed after earthquakes that have been felt in a large area
- **Physical damage** on the infrastructure elements

Event / Infrastructure	Inland /coastal floods	Earthquake	Tsunami	Sea Level Rise	High Temperature	Water Scarcity	High Wind / Storm
Submarine cable (deep sea)	Low	High	Medium	Low	Low	Low	Low
Submarine cable (near shore)	Low	High	High	Low	Low	Low	Low
Landing Station	High	High	High	High	Low	Low	Low
Terrestrial Cables (underground)	Medium	High	Low	Low	Low	Low	Low
Terrestrial cables (overland)	Low	Medium	Low	Low	Low	Low	Medium
Datacenters	High	Medium	Low	Low	Medium	Medium	Low
Antennas	Low	Medium	Low	Low	Low	Low	High

- **Interruption of power supply:** dependency to the electricity lifeline

Scope

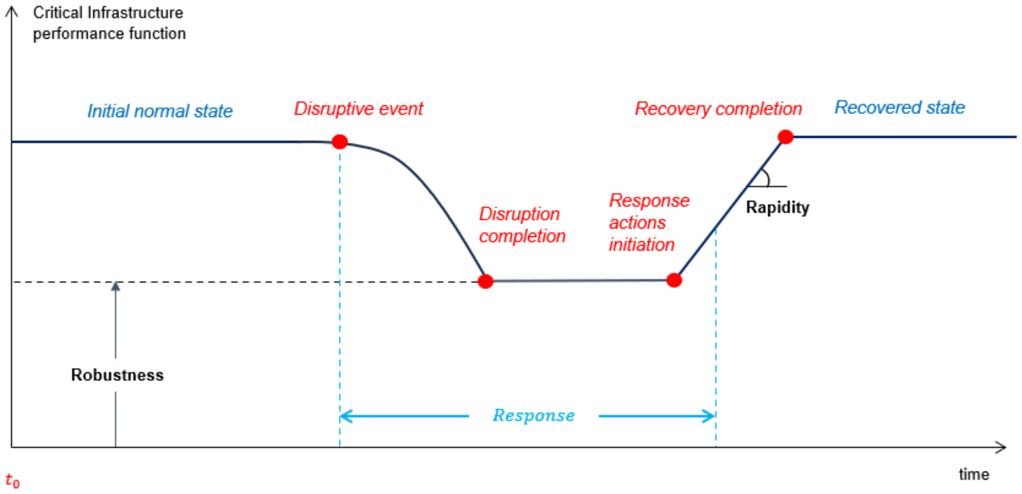
Fragments of the network

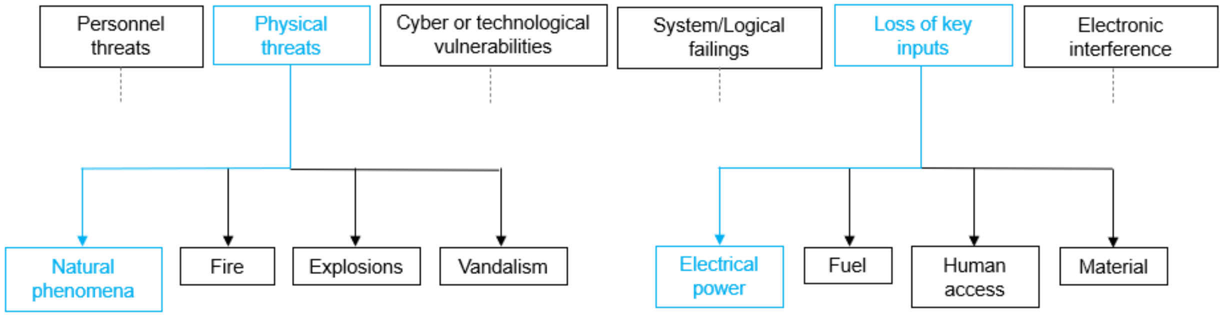
Core/transport networks

- meshed topology
- redundancy at site equipment
- back-up power

Access networks

- low path diversity
- low redundancy of equipment
- limited back-up power

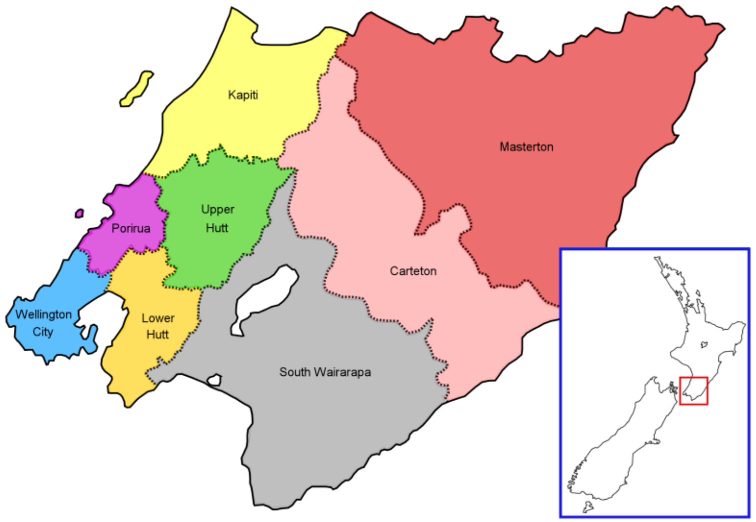




Assessment for response (1) - Systemic Approach

Geospatial analysis for the Community Emergency Hubs (CEHs) in the Wellington region (WREMO)

- **Multi-hazard** approach
- Study of **dependencies**
- Focus on the telecom **fixed-line network** and **Wi-Fi access**
- Interconnection between **risk reduction** and **sustainability**, with the use of **decentralized power generation** and back-up

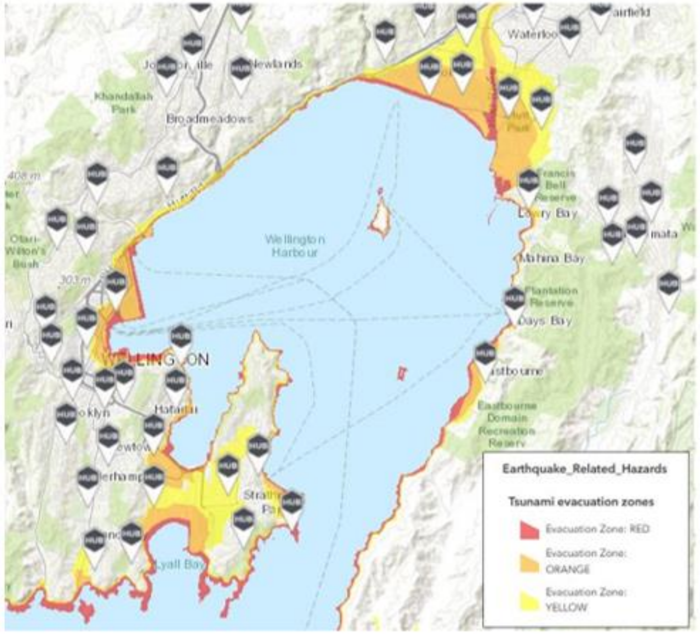


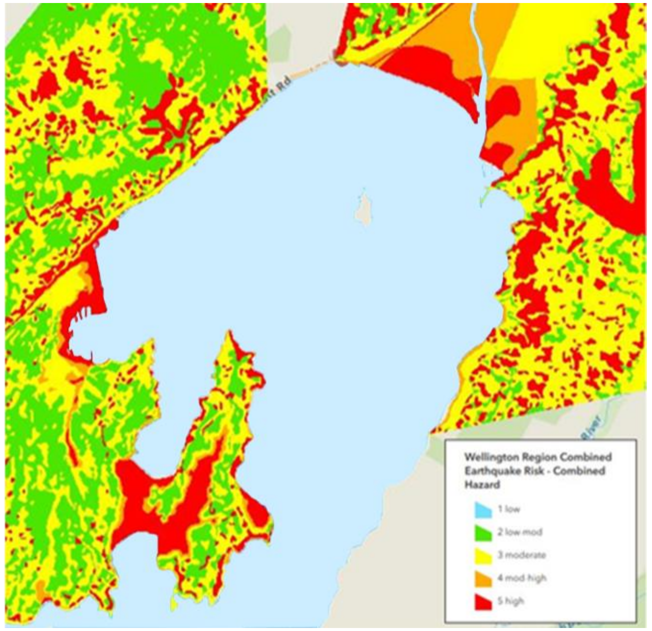
Community Emergency hubs
- 127 sites in the Wellington region
- Pre-identified places that activated in case of emergency to support communities
- Centralization and sharing of information and resources
- Presence of emergency kits which include a VHF radio
- Presence of a Wi-Fi router

Assessment for response (1) - Systemic Approach

Geospatial analysis for the Community Emergency Hubs in the Wellington region (WREMO)

- Hazards and susceptibilities



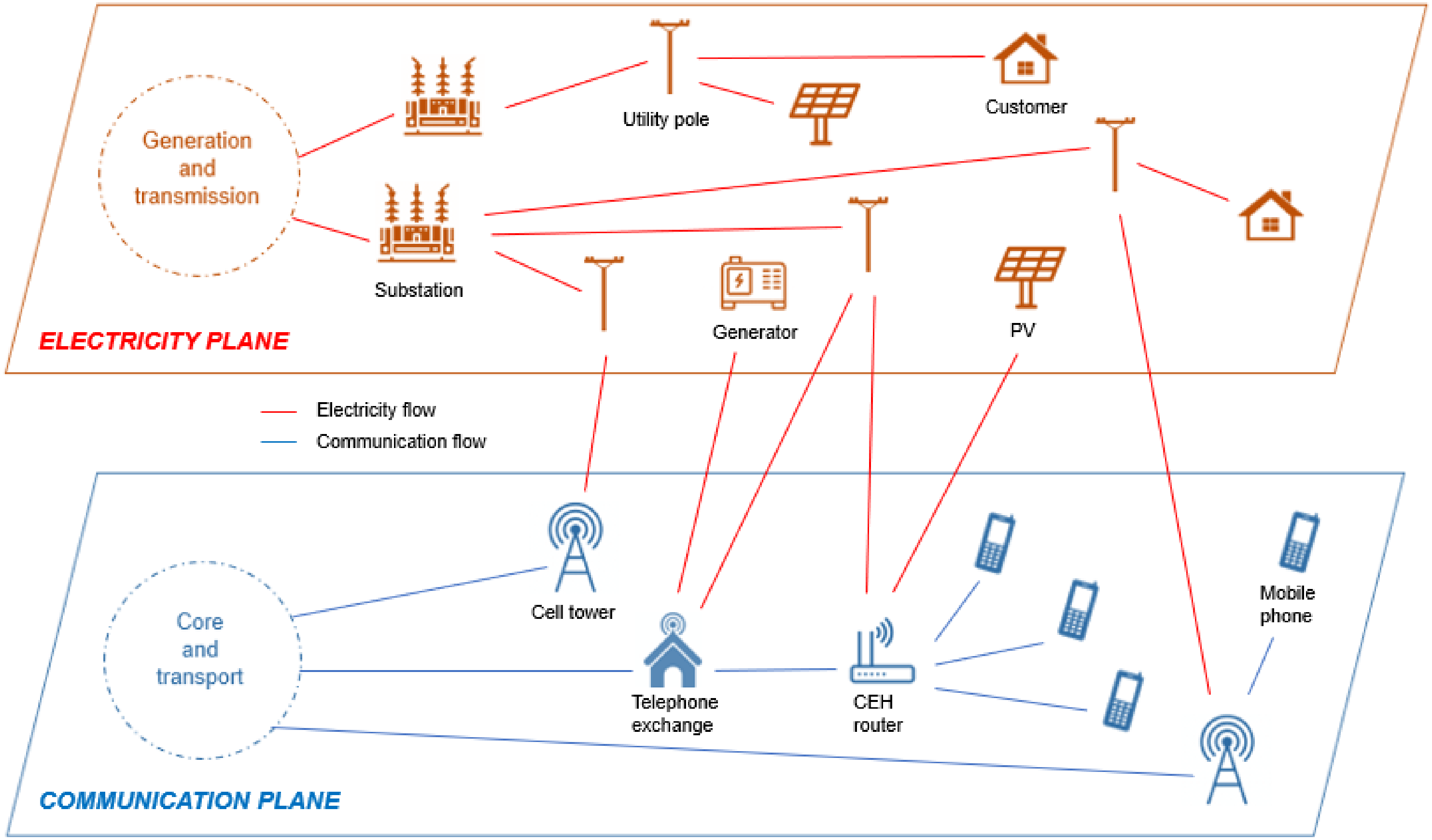


- Exposure analysis of the optical fiber that connects the CEH to the first telephone exchange

Assessment for response (1) - Systemic Approach

Geospatial analysis for the Community Emergency Hubs in the Wellington region (WREMO)

- **Dependencies**: assessment of power backup (for the hub and the telephone exchange)



Step 1

Does the community emergency hub have a resilient telecom/electricity system?

Selection of the CEHs based on the following criteria:

- Optical fiber connexion
- Wi-Fi router
- Solar panels + inverter
- Batteries

Step 2

Does the telephone exchange the emergency hub is connected to have an energy back-up system?

Consideration of the following criteria for the exchanges:

- Generator
- Fuel storage capacity

Assessment for response (1) - Systemic Approach

Geospatial analysis for the Community Emergency Hubs in the Wellington region (WREMO)

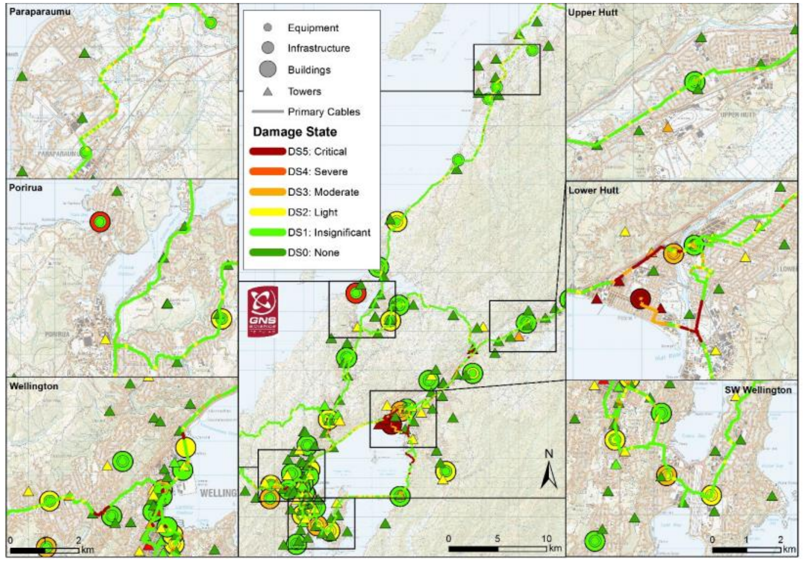
- **Scenario** of a M7.5 Wellington Earthquake

Step 3

How does the telecom infrastructure perform during a scenario and what is the consequence of other infrastructure services' outages?

Consideration of the following aspects:

- Damage level on the telecom infrastructure
- Electricity and road outage duration

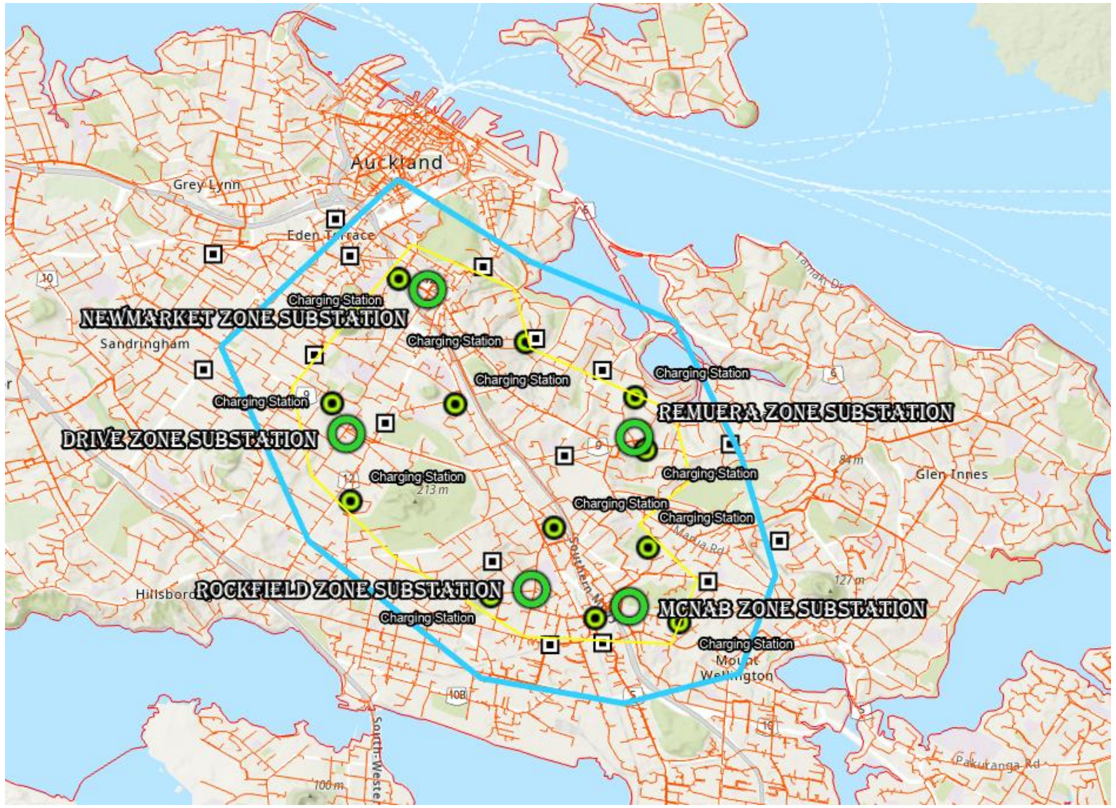


- **Ranking** of CEHs and **identification** of sites appropriate for installation of back-up power

Community Emergency Hub ID	CEH - Hazard Exposure			CEH - Telecom		CEH - Electricity		Telephone exchange		Scenario	
	Tsunami Evacuation zone (Yes/No)	Flood zone (Yes/No)	Combined Earthquake Hazard	WiFi router (Yes/No)	Risk for the fiber	Solar panels (Yes/No)	Batteries (Yes/No)	Generator on site (Yes/No)	Autonomy (Days)	Level of damage for the exchange	Road outage (Days)
1	No	No	3/5	Yes	Low	No	No	Yes	15 days	Low	10 days
2	No	No	1/5	Yes	Low	Yes	Yes	No	-	Low	7 days
3	Yes	No	1/5	Yes	Low	Yes	Yes	Yes	2 days	Low	14 days
4	Yes	Yes	4/5	Yes	High	No	No	Yes	15 days	High	14 days

Electric Vehicles and Emergency

Bing Yan, Zhenyang Wang



Electric substations, in a context of Peer-to-peer energy sharing

- Power quality and disruption mitigation
- Emergency situations: back-up power to critical facilities

Factors for the choice of location of stations

- Local distribution network
- Zone substations
- Busy roads and motorways.
- Traditional main gas stations

Assessment for response (2) - Data science approach

Modelling and **Monitoring** electricity outages during natural disasters

Context and Statement of the problem

Hazard

- Development of sensing technologies
- Availability of real-time monitoring data, with improvements of resolution (temporal and spatial)

Electricity

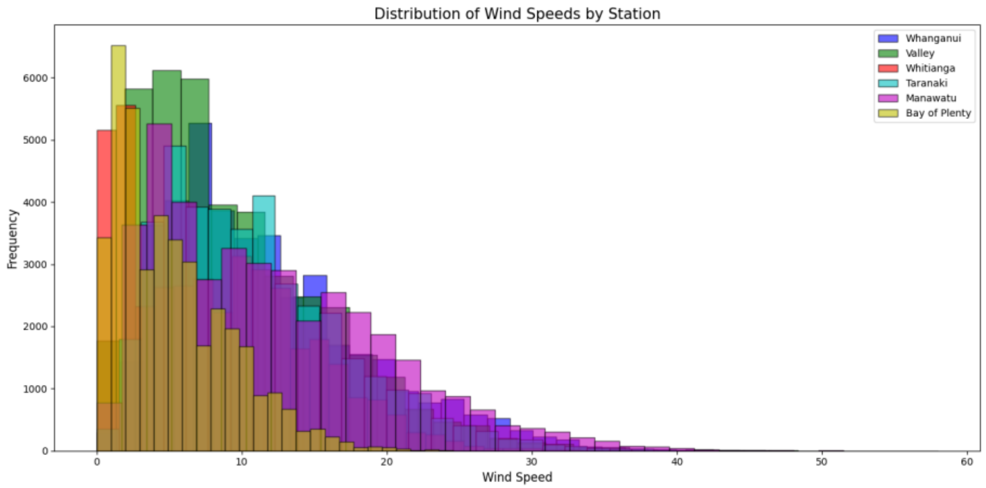
- Association of resilience to high-impact and low-probability (HILP) events
- Contribution of Distributed Energy Resources (DERs) to resilience, and to situational awareness

Machine-learning techniques

- Applications to response to natural disasters, mostly with satellite and social networks data
- Limited work with outage data

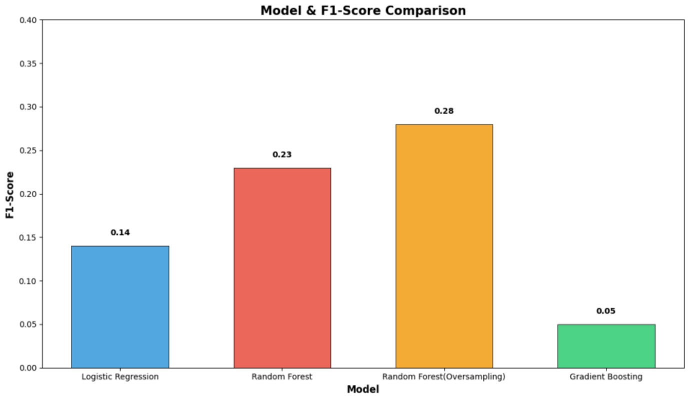
Power systems resilience to high hazard weather events

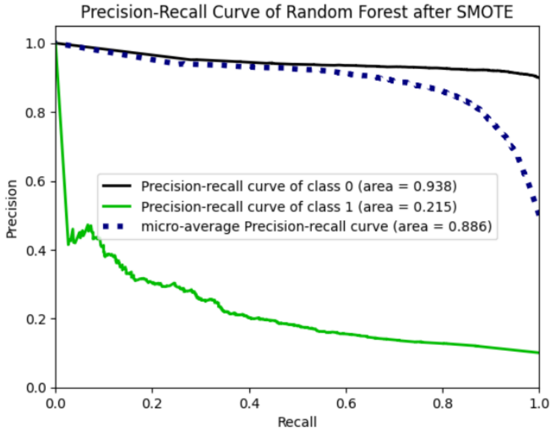
Sam Robinson, Hemanth Sonthi



Machine learning outage prediction model, for wind-related events

- NIWA wind data
- PowerCo outage data





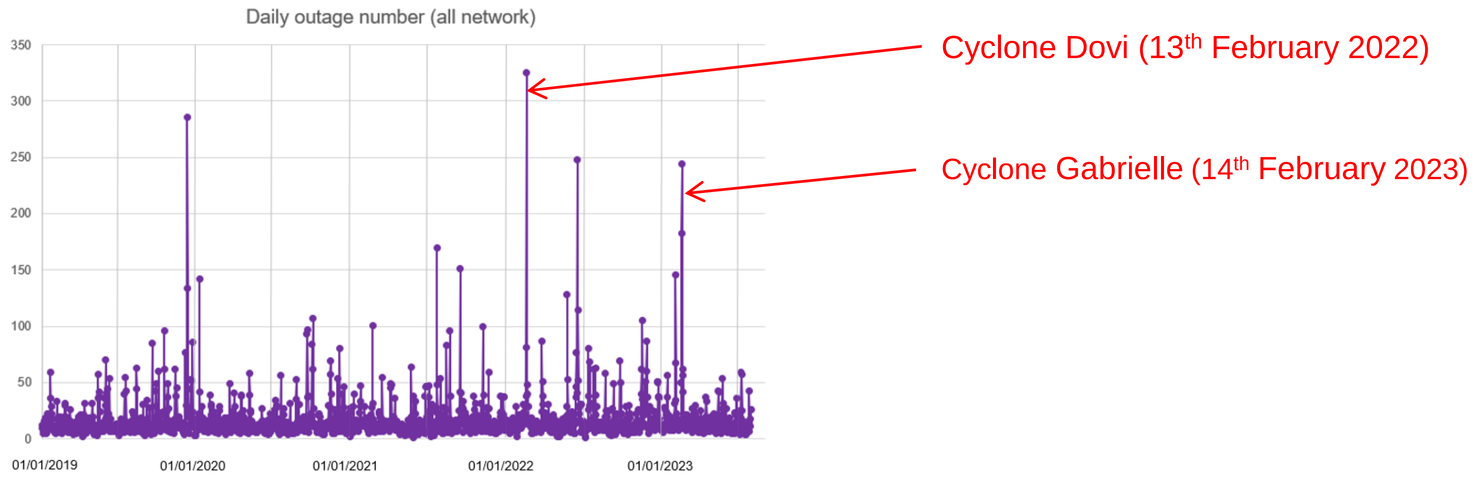
Directions for improvement of the model

- Higher spatial and temporal resolution for the wind data
- Architecture of PowerCo network
- More diverse range of resilience events and scenarios

Assessment for response (2) - Data science approach

Modelling and **Monitoring** electricity outages during natural disasters

Objective: Rapid impact assessment of the distribution lines



Approach: Architecture that also considers the data from distributed resources
Transfer to other distribution networks

Expected outcomes: identification of

- the areas with power interruption after the event
- the cellular stations which are likely to experience power outages

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Thank you!