# Developing a 'live' map of spatial access to health services in Aotearoa New Zealand

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**Abstract**

This paper outlines the development of a proof-of-concept real-time model that incorporates current road conditions to estimate spatial access to health services daily, at the address level. National Highway road-closure data was collected from the New Zealand Transport Agency (NZTA) Application Programming Interface and local road closure data was scraped from council websites. An OpenStreetMaps (OSM) road network was modified daily by removing any closed roads. The distance from each address in the Manawa Taki Health Region, through this new road network, to the nearest Hospital was calculated. The program was automated to run each day in January, using current road conditions for that day to estimate hospital accessibility. Daily estimates of hospital accessibility were successfully automated, with variations in spatial accessibility over time noted. However, the importance of data quality for the accuracy of this model is paramount. Reporting structures and formats meant that data obtained from some local councils was found to be imprecise or unreliable. This approach shows potential for quickly estimating access to health services under changing road conditions, such as during and after extreme weather events. NZTA and local councils are encouraged to work together to improve the quality and interoperability of road closure reporting.

## 1. Introduction

Many countries experience systematic and unfair differences in health, called health inequities, and working to achieve health equity means eliminating disadvantage beyond the control of individuals (Commission on the Social Determinants of Health, 2008). The health system is a fundamental determinant of health that can both reduce or exacerbate inequities (Commission on the Social Determinants of Health, 2008). While factors such as the quality of health care and discrimination are fundamentally important (Harris et al., 2013) ensuring spatial equity of health services is a core step to achieving health equity (Dalton et al., 2013). Spatial equity research generally examines how fair the distribution of access to a resource is across a population or geographic area (Whitehead et al., 2019). In the Aotearoa New Zealand (NZ) context spatial equity can be thought of as a 'needs-based' distribution of resources, where populations and places with higher health needs should have appropriately higher access to services (Whitehead et al., 2019). Equitable access to health services is therefore a very important issue, especially for priority populations, such as Māori (NZ's Indigenous people) and Pacific people, that experience persistent and entrenched health inequities (Whitehead et al., 2024). The recent health system reforms and Pae Ora (Healthy Futures) Act 2022 also recognise that Rural people experience health disparities and are therefore a recognised priority population.

More than a million people, approximately 20% of the total population and 25% of Māori, live in rural NZ. Rural New Zealanders are older and have higher levels of socioeconomic deprivation (Whitehead et al., 2024). An emerging body of research is also beginning to highlight the inequitable health outcomes experienced by rural people, and particularly rural Māori (Crengle et al., 2022). These include significantly higher mortality rates from preventable causes and lower vaccination rates (Whitehead et al., 2022; Liepins et al., 2024). Despite these poorer health outcomes, rural populations also experience lower levels of access to hospital care (Nixon et al., 2024).

The NZ Ministry of Health's first ever Rural Health Strategy (2023) emphasises the necessity for improved service access, yet a critical gap remains: spatial inequities in healthcare access in these communities have not been comprehensively studied. Compounding these issues are the impacts of climate change and extreme weather events, which disproportionately affect rural areas (Ministry of

Health, 2023) leading to further isolation (Pincham et al., 2024) and exacerbating already poor health outcomes and inequities, particularly for remote Māori (Jones et al., 2023).

The first step to improving access, is understanding current levels of access in nuanced detail. While a comprehensive study of access to health services in rural Aotearoa has not yet been completed, it is highly likely that many of these poorer outcomes are associated with worse access to health services. Research to better understand these challenges is important and must also reflect the realities of rural and priority communities. High quality information is needed to make evidence-informed decisions about how to improve services accessibility, with the aim of achieving more equitable outcomes. However, generic models of health service accessibility tend to under-estimate travel times for rural (and especially remote) populations who live in areas with road networks that are more vulnerable to disruption. This can be caused by extreme weather events, road crashes, or routine maintenance that closes or significantly slows sections of road for long periods of time - often with no alternative routes available.

In 2024 we were awarded University of Waikato Strategic Research Funding grant to build upon novel data processing, storage, and analysis techniques developed by the Centre for Australian Research into Access (CARA) at Deakin Rural Health, and rural health and demographic expertise at Te Ngira: Institute for Population Research at Waikato University. As part of an Australian Research Council (ARC) Linkage Infrastructure, Equipment and Facilities (LIEF) Grant (Australian Research Council, 2019), CARA developed a high-speed process for calculating road time and distance metrics between the location of dwellings and services at a continental scale. This network analysis has three components.

1. A collection of starting points or **origins** (private dwellings) from which measures are made.

2. A **network** of lines composed of nodes and segments that model the topology, restrictions (one/two-way, overpasses etc.) and traffic speeds associated with the road network.

3. A collection of end points or **destinations** (services) to which measures are made.

These components are used to calculate shortest times and distances from origins to destinations by traversing the network using the Dijkstra's algorithm enhanced by applying a Contraction Hierarchy heuristic. This algorithm is implemented in C++ and enabled as a Python library called Pandana. Pandana is developed by UrbanSim at the University of Berkley (Foti & Waddell, 2012).

The ability to calculate metrics directly from every dwelling to the building within which a service is located, allows the output metrics to be both independent of any arbitrary spatial unit and produce metrics for any type of area. It also means that they are free from the statistical biases and constraints imposed by arbitrarily aggregation such as the Modifiable Areal Unit Problem (Openshaw, 1984) and the Ecological Fallacy (Openshaw, 1984).

Together the Te Ngira: Institute for Population Research and CARA developed a proof-of-concept model to estimate New Zealanders access to health services at the address level. This proof-of concept used entirely open-source datasets, including the OSM Road Network, Ministry of Health published health facility locations, and a Land Information New Zealand address dataset.

Further extending this work, we then applied our approach to a case study: rapidly examining the impact of Cyclone Gabrielle in 2022 on the accessibility of health services (Pincham et al., 2024). We estimated the distance to nearest General Practice (GP) service and Hospital for each of the 2.3 million addresses in NZ under “normal” conditions. We then modified the road network dataset to reflect road closures immediately following Cyclone Gabrielle, and access to services was estimated under new conditions. We found that road closures had a significant impact on service accessibility, with 93,140 addresses becoming isolated from GP services, and 108,810 addresses becoming isolated from Hospital services. An additional 24,021 addresses experienced increased travel to GP of more than 1km, while 132,686 addresses experienced increase travel to a hospital (Pincham et al., 2024). Service accessibility disruptions had a disproportionate impact on rural, Māori, and Older (age 65+) populations, as well as areas of high socioeconomic deprivation (Whitehead et al., 2025).

While this research was an important methodological and conceptual advancement, highlighting the impact that extreme weather events can have on the spatial accessibility of services, a ley limitation was identified. The status of the road network is dynamic, and it was unclear how long different sections of the road network were closed for.

While our previous work provides a useful ‘snapshot’ of disruption to spatial accessibility, it does not reflect changes to access over time. This paper builds on our approach by attempting to develop a real-time model that incorporates current road conditions to estimate spatial access to health services daily, at the address level.

## 2. Method

### 2.1 Datasets

Datasets used in this research include: (1) OpenStreetMap (OSM) Road Network Dataset, accessed 17/02/2024; (2) Land Information New Zealand (LINZ) ‘NZ Addresses’ dataset (LINZ, 2024); and the Te Whatu Ora Health New Zealand (2024) 'Facility code table', which was used to identify the geographic location of all publicly funded hospitals. The Facility code table lists all health facilities in NZ and provides xy geospatial coordinates for each facility, including for 83 hospitals.

In NZ, the Government Roading Powers Act 1989 and Local Government Act 2002 define the functions and powers of the New Zealand Transport Authority (NZTA) and local authorities in relation to motorways, state highways and land transport. In essence, the responsibility for maintaining roads and setting speed limits on National Highways falls to NZTA – a government organisation, while local councils are responsible for local roads within their area. Therefore, information about National Highway road closures was collected using the NZTA Application Programming Interface (API). Information about 'local' road closures was identified and scarped from local council websites.

### 2.2 Modifying the road network to reflect disruptions

Once information about National Highway and local road closures had been collected the OSM road network could be modified, following previously developed methods (Pincham et al, 2024), to reflect current roading conditions.

The NZTA API provided detailed geospatial information about which sections of National Highways were closed. This API provided geometry Point and MultiLineString objects. The Points were used to identify the closest node in the road network, which was flagged for removal. Several different methods to use the MultiLineStrings were experimented with. These included exploring the intersection between NZTA closure 'lines' with OSM network 'lines'; identifying OSM points within a 'delta' distance of NZTA closure "lines'; and using polygon buffers around NZTA closure 'lines'. It was determined that the only effective approach involved reducing the MultiLineString provided by the API down to a set of Points at each bend, meaning that these derived points could be used to identify the closest relevant road points in the road network. These identified road network points were then removed as were the edges which connect these points. The final step was to recompile the new 'broken' OSM road network using the python programming library Pandana.

Unfortunately, road closure information from local council websites was of varying quality. Some councils provided a geospatial display of road closure data, or an organised table or list of the road status with clear classifications differentiating between closures, warnings, or delays. This assisted the efficient and effective gathering of road network disruption data. Other councils provided information in an inconsistent manner, with different webpage layouts and different ways of classifying the road network status. Some councils only provided further information about each notice on an external webpage, adding an extra obstacle to effectively gathering data.

Each council's webpage was scraped individually. For a page with organised data, specific tables and columns could be referenced in the script, allowing the collection of more detailed classification information (e.g. type of disruption). In order to use road closure information that was not consistently organised, regular expressions were used to filter for the names of closed roads on the webpage. Since this approach does not allow for classification information to be gathered, all road names collected in this manner were treated as road closures. This is likely to overestimate the number and extent of road closures within those council areas where the quality and consistency of road disruption information is lower.

The 'edges' of any closed highways, or local roads were removed from the road network, which was then recompiled using the Pandana python programming library.

### 2.3 Estimating address level access to health services

The travel distance from each address, through the updated road network, to the nearest Hospital was then calculated using methods developed by CARA. The network model calculates the road network distance between every address point in the Manawa Taki health region, to its nearest Hospital.

In order to examine potential data quality issues between NZTA and council information, the model was run twice through two networks. One network only included the NZTA highway road closures while the other network had removed road closures from both NZTA and councils.

The entire program was automated to run each day between 1st and 31st of January 2025. Each day, local and national road conditions for that day were used to modify the OSM road network, and the distance from each address to the closest hospital was estimated using a unique road network. This allowed an examination of the impact of changing daily road conditions on access to health services.

## 3. Results

The goal of developing a real-time model that incorporates current road conditions to estimate spatial access to health services daily, at the address level, was successfully achieved. The model took approximately five minutes to gather the necessary data, modify the OSM road network, and to calculate the distance to nearest hospital for approximately 2.3 million addresses in NZ.

However, during the test period of January 2025, there were no extreme weather events or major disruptions which could have severely impacted the road network. This meant that it was difficult to comprehensively test the effectiveness of the program during a disaster scenario.

Examining the daily 'distance to nearest hospital' maps using only NZTA highway disruptions data showed almost no changes in access to hospital services across month of January.

Integrating road closure data from local councils did indicate changes to hospital access across the study period. However, it is important to keep in mind that this is likely to be impacted by differences in data quality across different councils.

Figure 1 shows the distance to nearest hospital for every address in the Manawa Taki health region of NZ on January 1st, 2025.

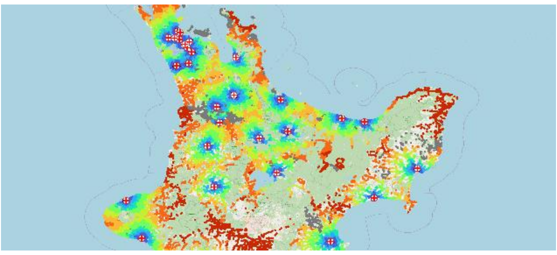

Figure 1 Distance to nearest hospitals on January 1st for the Manawa Taki health region. Red addresses are further from Hospitals, while blue addresses are closest.

Figure 2 shows changes in distance to nearest hospital for every address near Raglan due to road closures in January 2025.

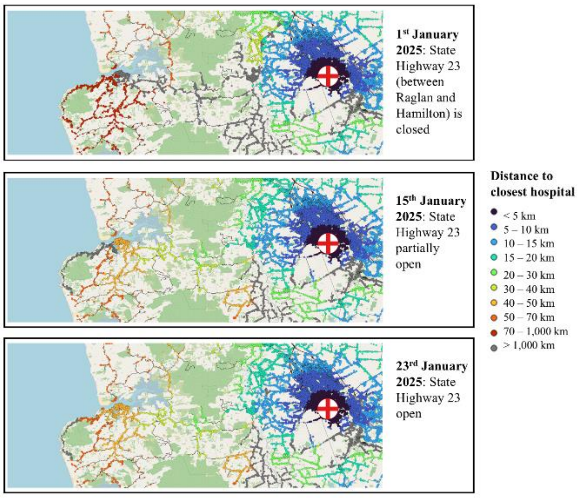


Figure 2. Changes to hospital access near Raglan on January 1st, 15th and 23rd 2025.

The results also highlight inconsistencies in the quality of council data about road disruptions, with clear divisions between councils observed in Figure 3. Council boundaries can be observed in the patterning of disruption, implying missing or poor-quality data being provided by some councils.

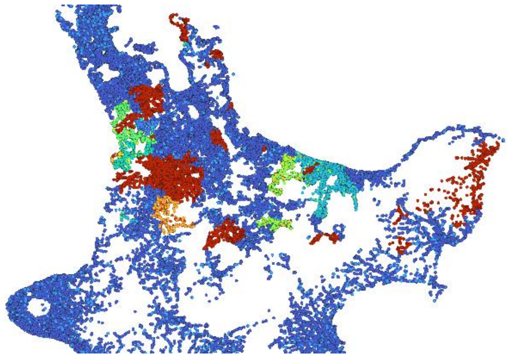

Figure 3. Number of days of disrupted access between 1st and 30th January 2025. Blue indicates addresses with 0 days of disrupted access, while red indicates 23 days of disrupted access.

This is an important issue to acknowledge. The quality of road closure information was reviewed for a subset of 21 councils across the wider Manawa Taiki region (see Table 1). Fewer than 15% of councils in the region provided the geospatial information about road network disruptions that would be required to efficiently and accurately identify the exact location and extent of road closures in each area. In addition, more than half of councils (57%) did not provide road disruption information using a consistent layout that would support efficient automated collection.

| Council | GIS Info | Time-frame | Activity Info | Consistent layout |
|---|---|---|---|---|
| Thames-Coromandel | FALSE | TRUE | TRUE | FALSE |
| Hauraki | FALSE | TRUE | TRUE | TRUE |
| Waikato | FALSE | TRUE | TRUE | TRUE |
| Matamata-Piako | FALSE | TRUE | TRUE | FALSE |
| Hamilton | FALSE | TRUE | TRUE | FALSE |
| Waipā | FALSE | TRUE | TRUE | FALSE |
| Ōtorohanga | FALSE | TRUE | TRUE | FALSE |
| South Waikato | FALSE | TRUE | TRUE | FALSE |
| Waitomo | FALSE | TRUE | TRUE | FALSE |
| Ruapehu | FALSE | TRUE | TRUE | FALSE |
| Taupo | FALSE | TRUE | TRUE | TRUE |
| Rotorua | FALSE | TRUE | TRUE | TRUE |
| Western Bay of Plenty | FALSE | TRUE | TRUE | FALSE |
| Tauranga | FALSE | TRUE | TRUE | FALSE |
| Whakatāne | TRUE | TRUE | TRUE | TRUE |
| Kawerau | FALSE | FALSE | FALSE | FALSE |
| Ōpōtiki | FALSE | TRUE | TRUE | FALSE |
| New Plymouth | TRUE | TRUE | TRUE | FALSE |
| Stratford | FALSE | TRUE | TRUE | FALSE |
| South Taranaki | FALSE | TRUE | TRUE | FALSE |
| Gisborne | TRUE | TRUE | TRUE | TRUE |

Table 1. Quality of council road closure data within the Manawa Taki Health Region of New Zealand

Furthermore, local councils differ on how they report road conditions and road closures. Some councils report road works, while others only report road closures, which appears to have impacted our results. For example, almost all of Waipa district experienced changes in access to hospitals across the period, while the Hauraki and

Matamata-Piako districts appeared to have relatively little road network disruption. This difference is highly likely to be due to differential reporting of road works and other disruptions, rather than any real difference in service accessibility between these regions.

## 4. Conclusions

Overall, the goal of using 'live' information about road closures to estimate changes in access to hospital services was achieved. This process has been automated and uses a model of estimating access developed by CARA which together allow the rapid estimation of daily health service accessibility.

However, some significant challenges were noted, and arguably our most important research finding is around data quality. Differences in how NZTA and local governments report road disruptions appear to be the biggest barrier to effectively monitoring daily changes to health service accessibility. While NZTA and some (likely better resourced) councils provided detailed geospatial information about disruptions, and differentiated between closures and delays, this was not consistent across all council regions.

While this was a frustrating limitation of this research project, it also has important implications for emergency response coordination. In an emergency, both national and local emergency response organisations and first responders will require accurate and up-to-date information that supports their response. Local residents would also require accurate and detailed information about their local area in order to support safe and efficient evacuation, including the ability to identify the best route to seek food or medical attention.

As climate change continues to increase the frequency and severity of extreme weather events a consistent and coordinated approach to collecting and providing high quality and interoperable information about the road network is growing in importance.

While future research could aim to improve and further develop our method of extracting road information, we would argue that maintaining the digital infrastructure of a national asset should be considered just as important as maintaining its physical infrastructure. We would urge NZTA and councils to work together, alongside academics and emergency response organisations such as the National Emergency Management Agency (NEMA) and local Civil Defence authorities to improve the quality and availability of road network data.

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