A distance-based approach to rurality and remoteness in health: concept, methodology and correlates of a patient-centred health services spatial accessibility index

Emmanuel Jo, Chris Lane, Keri McArthur, Fei Xu

How many health practitioners will be required to meet the needs of patients in rural and remote areas in New Zealand in future years? That was a question that the analytics team in the Health Workforce Directorate of the Ministry of Health was trying to answer, but there wasn't a reliable way to identify which rural and remote patients should be targeted. To identify such rural and remote patients, the team calculated a "distance score" based on how far they live from primary care facilities and from hospitals with extensive specialist and emergency services. The 20% of patients with the highest distance scores live mainly in smaller towns and rural and remote areas and have a relatively high proportion of older people, Māori and people living in high socioeconomic deprivation. Being able to identify these patients means the Ministry of Health has a better understanding of which health services are currently serving these patients and where resources need to be put to improve services to them.

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ABSTRACT

AIM: To develop a distance-based index of patients' spatial accessibility to healthcare services as a quantifiable basis for analysing health services and health outcomes in urban, rural and remote locations.

METHOD: A distance score was calculated based on each primary health organisation enrollee's shortest distance to the nearest primary care facility and to the nearest secondary or tertiary hospital. The distance scores were then grouped into ten distance deciles (DDs).

RESULTS: When these DDs are compared with Stats NZ's urban-rural indicator, "small urban areas" fall mainly along with rural and remote areas into the two DDs (DD9 and DD10) based on the greatest distance scores. When compared with Stats NZ's urban accessibility classification, the same two DDs correspond mainly to the most rural and remote areas. In both the North and South islands, 25% or more of enrollees in DD9 and DD10 are aged 60+. Of enrollees in DD10 in the North Island, 32% are Māori and 33% live in highly deprived areas (NZDep2013 deciles 9 and 10).

CONCLUSION: The results provide an initial validation of the patient-centred health services spatial accessibility index as a measure of rurality and remoteness for analysis of health service provision and health outcomes.

Concern about the provision of health services to rural and remote populations in New Zealand continues,[1–5] but relevant analyses of health service provision and health outcomes have been hampered by a lack of a clear and consistent framework for distinguishing urban, rural and remote locations from a health perspective. It is possible to routinely analyse health conditions, health-related behaviours and health outcomes by age, gender, ethnicity and socioeconomic deprivation, but not by urban, rural or remote locations. At the Health Workforce Directorate (the Directorate) of the Ministry of Health (the Ministry), we provide funding for the training of general practitioners (family physicians, GPs) and have sought to make sure that GP trainees gain experience in serving rural and remote communities. More broadly, the Directorate has also sought to understand the distribution of primary care practices and their patients in rural and remote communities. In 2018, the Analytics and Intelligence section in the Directorate developed an approach to rurality and remoteness that focuses on "spatial access."[6] This has improved our understanding of differences among primary care practices and contributed to analysing the placement of resources

for general practice training. This approach was updated in 2020 to provide a flexible tool for analysis and forecasting, which we have incorporated (along with regional and patient demographic variables) in a model for forecasting future demand for primary care services in rural and remote areas. This spatial accessibility index has been developed independently of the Geographic Classification for Health[7] and is complementary to it.

This paper describes the development of the patient-centred health services spatial accessibility index in terms of the concept, the data used and the calculation of the index. This index is then compared with two of Stats NZ's indicators of rural-urban differences, and use of the index is illustrated in terms of how it relates to other factors potentially linked to health outcomes.

Defining urban and rural

Since 2001, Stats NZ has had two general approaches to classifying urban and rural areas: one based on population density, and the other based on patterns of travel or potential travel. More specifically, the first approach distinguishes urban areas by their total population and rural areas by whether there are local concentrations of population ("rural settlements").

The earliest version of the second approach was the urban-rural experimental profile (UREP).[8] This was based on patterns of commuting between home and work addresses found in census data.

Both classifications have been assessed as a basis for identifying rural as opposed to urban. Both have also been found to be problematic from the perspective of analysing healthcare.[9] One issue relates to small urban areas that are relatively distant from larger urban areas but where the health services cater for a largely rural population. This is not well accounted for in either classification. Fearnley, Lawrenson and Nixon proposed a modification to UREP to better represent urban and rural health provision, but even with this modification, we have found UREP unsatisfactory because it does not take into account the actual locations of hospitals and other health facilities.

Stats NZ recently released a new travel-based "urban accessibility" classification, this time based on driving times to larger urban areas from locations outside them.[10] This classification is considered in more detail below in comparison with the spatial accessibility index.

At the time of developing the spatial accessibility index, there was an existing Rural Ranking Scale (RRS) for general practitioners, based on their on-call duties, their coverage of peripheral clinics and three distance-based measures: travelling time to a major hospital, travelling time to the nearest GP colleague's place of work and travel time to the most distant practice boundary.[11] These distance-based measures were based on the location of each general practice, rather than the locations of their patients.

Method

The Health Workforce Directorate of the Ministry of Health sought a measure of rurality/remoteness that reflects where patients live rather than where general practitioners work. So, we adapted the hospital-distance and distance-to-practice measures in the RRS to ones that apply to patients. As a result, the Directorate developed a measure of the spatial accessibility of health services based on the distance of primary health organisation (PHO) enrollees' locations from the nearest secondary/tertiary hospital and from the nearest primary care facility (this category includes general practices led by GPs and by nurse practitioners, urgent care clinics, primary hospitals, hauora Māori/Māori health providers, Pacific health providers and tertiary education student health centres).

The Ministry of Health retains data on healthcare facilities and on enrollees (identified by their National Health Index numbers (NHIs)) in which locations are specified on a longitude (X) and latitude (Y) grid. As Ministry employees, we had access (under the provisions of the Health Information Privacy Code[12,13] allowing use for statistical purposes) to data on 4.7 million New Zealanders enrolled in PHOs. This was reduced to an analysis dataset of 4.6 million validated PHO enrollees after removing invalid NHIs and those without valid X and

Y coordinates. We put our use of this data in front of the Health and Disability Ethics Committees, Ministry of Health, and were advised that as "an Audit or related activity it does not require HDEC review."[14] We used a PHO enrollee dataset extracted from the National Enrolment Service (NES) at March 2020.[15] We measured the distance "as the crow flies" between each enrollee's location and the nearest primary care facility and the nearest secondary or tertiary hospital (these are hospitals with the capacity (24 hours a day, seven days a week) to provide acute surgery under general anaesthesia and to regularly undertake Caesarean sections: the 24 such hospitals are listed in Appendix Figure 1). We then calculated a distance score by adding the home-to-nearest-primary-care straight-line distance and the home-to-nearest-hospital straight-line distance in a weighted proportion. The simplification to straight-line distances was required so that the necessary billions of calculations would be tractable.

The main weighting we have used is 30% primary care distance and 70% hospital distance, which is approximately in line with the weighting of practice distance and hospital distance in the RRS. That weighting is the basis of the analyses explored later in the paper. We compared this weighting with two other potential weightings (10%/90% and 50%/50%) on a national scale and found only small differences in the relative ordering of the distance scores and in the way that distance scores group into deciles, because whatever the weighting, the hospital distance accounts for most of the difference in distance scores.

The straight-line distances used will underestimate the actual travel distances for enrollees, but the point of calculating the distance scores is to estimate enrollees' relative distances from health facilities.

As of March 2020, we had counted 1,063 primary care facilities and 24 secondary and tertiary hospitals in New Zealand. Therefore, calculation of the distance score involved (4.6 million x 1,063) + (4.6 million x 24) = 5 billion distance calculations. SAS® 9.4 was used for the calculation of distance score and distance decile and further analysis.

The distance scores provide a patient-centred health services accessibility measure for each enrollee—"accessibility" here refers to spatial accessibility rather than financial, social or cultural accessibility. We grouped enrollees' distance scores into deciles (with 10% of enrollees in each, by definition) to produce a "distance decile" measure as a way of representing spatial accessibility. The distance decile approximates an urban-rural/remote continuum, with distance decile 1 being the most urban and distance decile 10 the most rural or remote. The boundaries between deciles (using a 30%/70% weighting) are shown in Table 1. The maximum distance scores are for enrollees in the Chatham Islands/Rēkohu/Wharekauri.

The average (mean) distance score of each primary care practice's enrollees was also calculated to produce a practice distance score, and then these practice distance scores were grouped into practice distance deciles.

The distance scores and distance deciles for enrollees and for primary practices were then available for analysis and modelling, together with demographic and health variables for enrollees and practice and practitioner characteristics for primary practices.

Table 1: Distance Decile lower and upper boundaries.

Distance decile	1	2	3	4	5	6	7	8	9	10
Lower distance score	0	1.6	2.4	3.2	4.1	5.3	6.7	10.7	18.7	32.7
Upper distance score	1.6	2.4	3.2	4.1	5.3	6.7	10.7	18.7	32.7	720.2

As a check on the distance-score measure, we took a random sample of 200 enrollees and compared their straight-line distance scores with distance scores calculated using road distances obtained from OpenStreetMap. Overall, the relationship between the road and straight-line distance scores was linear, with a correlation coefficient of 0.99. The ratios of road distance scores to straight-line distance scores were variable for small distance scores but more consistent for larger scores. For straight-line distance scores over 10.7 (ie, distance deciles 8, 9 and 10), the average ratio was 1.28 with a standard deviation of 0.15, compared with an average ratio of 1.49 and standard deviation of 0.33 for distance deciles 1 to 7. In distance deciles 8 to 10, there was one anomalous ratio of 1.88 where the road route to hospital had to skirt a mountain range. But for distance deciles 8 to 10 in general, the straight-line distance score represented a fairly consistent proportion of the road distance score.

The processes of extracting the enrollee data and calculating distance deciles are visualised in Figure 1.

Results

As an initial test of the spatial accessibility index, we compared the distance deciles with two of Stats NZ's urban-rural classifications and used the distance deciles to analyse the distribution of health-related factors in the North and South islands.

Distance decile compared with Stats NZ's urban-rural indicator

We compared our distance decile with Stats NZ's urban-rural indicator (IUR 2020). The urban categories in IUR 2020 are defined by population size: major urban (100,000+), large urban (30,000–99,999), medium urban (10,000–29,999) and small urban (1,000–9,999). Figure 2 shows the percentages of validated PHO enrollees in March 2020 in each IUR category within each distance decile (for the purposes of direct comparison, both classifications are defined on 2013 meshblocks, the geographical units used for the 2013 census).

The PHO enrollees at the greatest distance from secondary/tertiary hospitals and primary care practices are in distance deciles 9 and 10, and these enrollees are largely in rural or small urban areas.

For the purposes of analysing health services accessibility, distance deciles 9 and 10 can be taken as approximately equivalent to "rural/remote." Similarly, rural/remote can be more loosely approximated by the IUR 2020 categories "small urban area," "rural settlement" and "rural other."

Distance decile compared with Stats NZ's urban accessibility classification

Stats NZ recently (September 2020) released the urban accessibility classification, which is focused on rural areas and small urban areas and based on how long it takes to drive from those areas to the nearest larger urban areas (ie, major, large or medium urban areas, as defined for the urban-rural indicator).[10] The categories are:

- High urban accessibility (high UA): up to 15 minutes from a major urban area
- Medium urban accessibility: not high UA but up to 25 minutes from a major or large urban area, or up to 15 minutes from a medium urban area
- Low urban accessibility: not high or medium UA, but up to 60 minutes from a larger urban area
- Remote: 60 to 120 minutes from a larger urban area
- Very remote: more than 120 minutes from a larger urban area

Figure 3 shows the estimated percentages of validated PHO enrollees at March 2020 in each urban accessibility category within each distance decile. (The urban accessibility classification is defined over a 2018 census geographical base, whereas the distance deciles were calculated over 2013 census meshblocks. The geographical classifications for the two censuses differ somewhat due to population growth, hence the comparison between the urban accessibility classification and distance deciles is approximate.)

In terms of the urban accessibility classification, distance deciles 1 to 7 are largely urban, and distance decile 8 is mainly a mix of large and medium urban and high, medium and low urban accessibility. A large part of distance decile 9 (77%) consists

Figure 1: Data analysis and distance decile calculations.

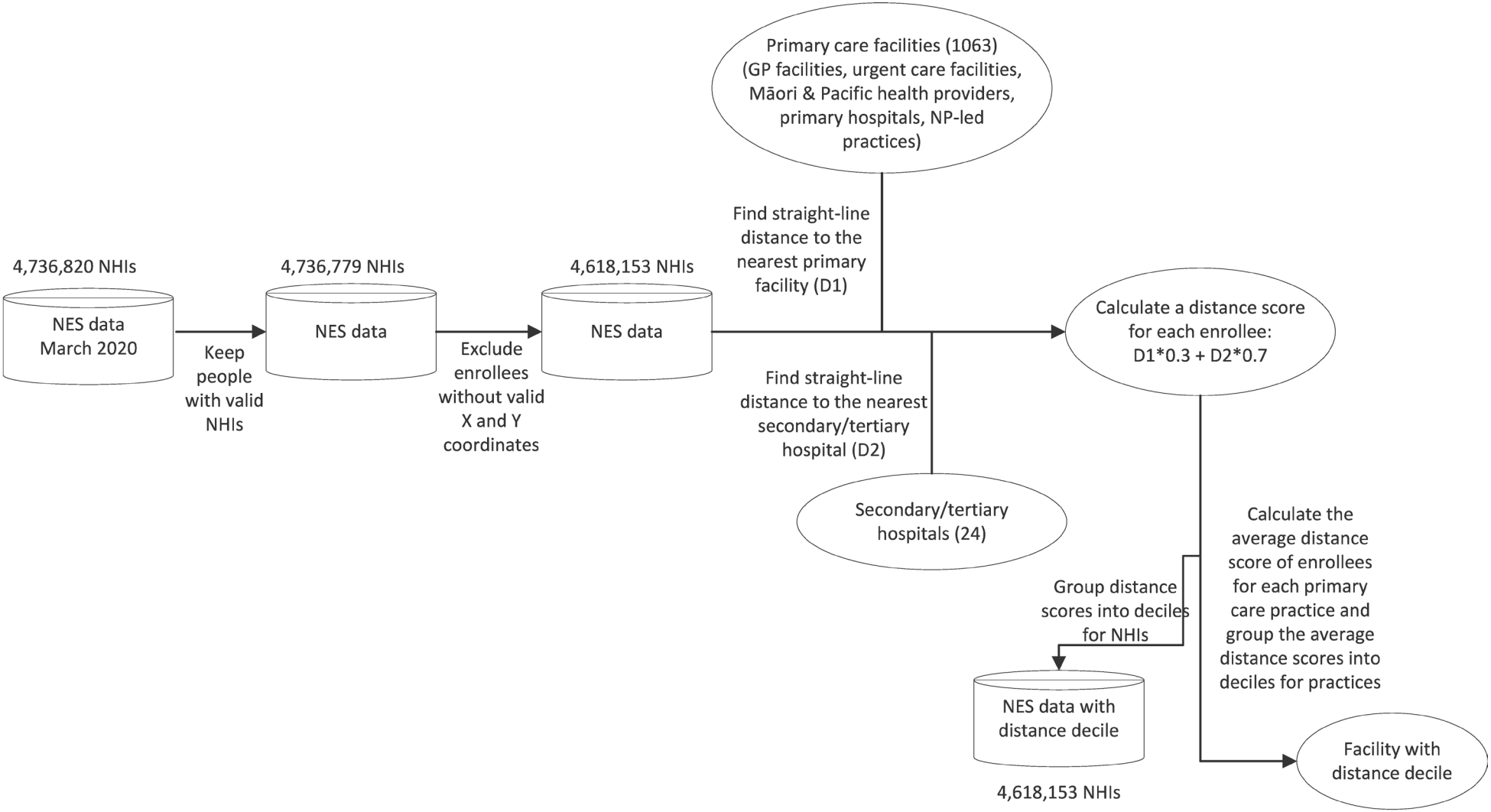

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Figure 2: Percentage of validated PHO enrollees at March 2020 in Stats NZ's urban-rural indicator categories (IUR 2020) in each distance decile (30%/70% weighting).

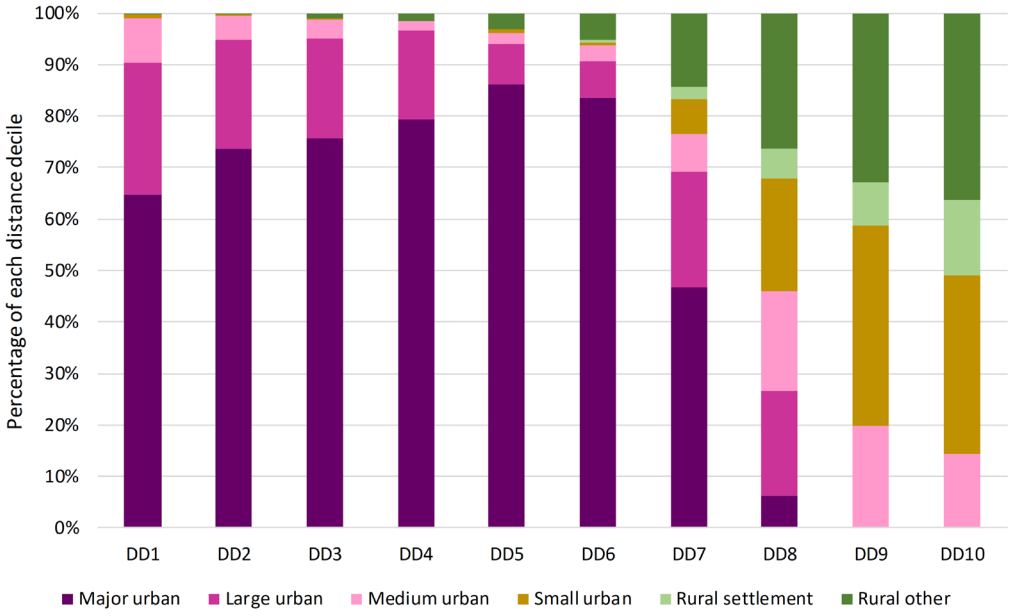
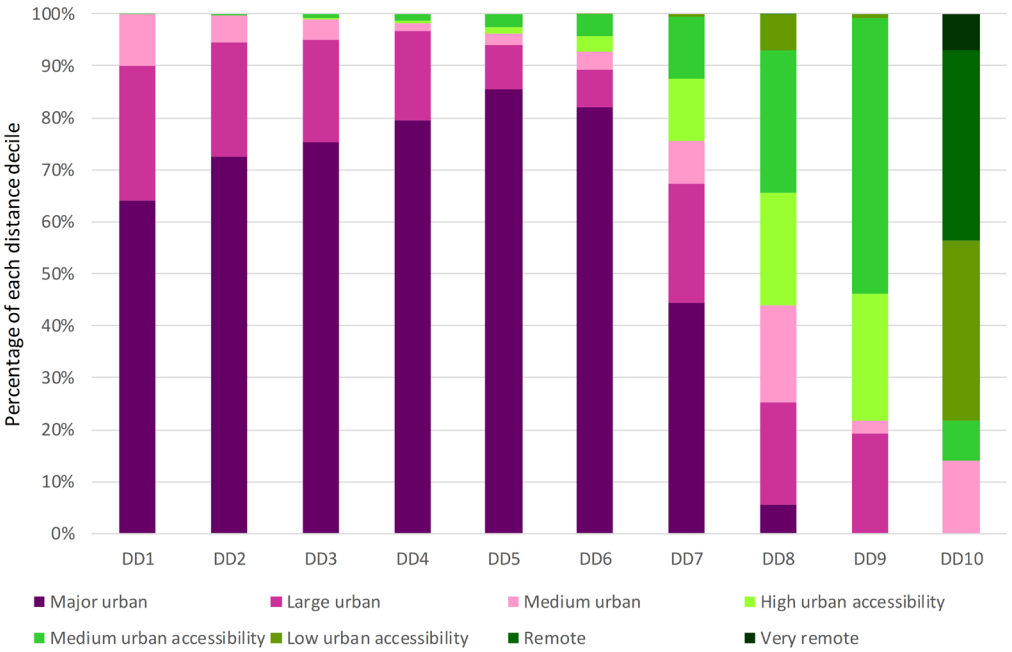


Figure 3: Estimated percentage of validated PHO enrollees at March 2020 in Stats NZ's urban accessibility categories in each distance decile (30%/70% weighting)



of areas with high or medium urban accessibility, as well as some large urban areas—these will be urban areas without secondary or tertiary hospitals and at a considerable distance from the nearest secondary/tertiary hospital. Most of distance decile 10 (78%) consists of remote or very remote areas or areas with low urban accessibility. However, distance decile 10 also includes some medium urban areas that are a long way from secondary/tertiary hospitals (eg, Queenstown and Taupō). In the urban accessibility classification, by definition such medium urban areas cannot be remote, because remoteness is based on distance from medium or larger urban areas.

In terms of distance deciles, all of the remote and very remote areas in the urban accessibility classification fall into distance decile 10, as do 82% of the low urban accessibility areas, whereas 50% of the medium urban accessibility areas and 41% of the high urban accessibility areas are in distance decile 9.

The two classifications show considerable agreement in terms of representing rurality and remoteness. A key difference is that the distance decile classification allows for the possibility that medium and large urban areas can be remote from secondary/tertiary hospitals.

Distance deciles in the North and South islands

The distance deciles are defined for the whole country: by definition, 10% of all validated PHO enrollees fall into each decile. However, the distribution of enrollees by distance decile is quite different in the two islands, as shown in Figure 4.

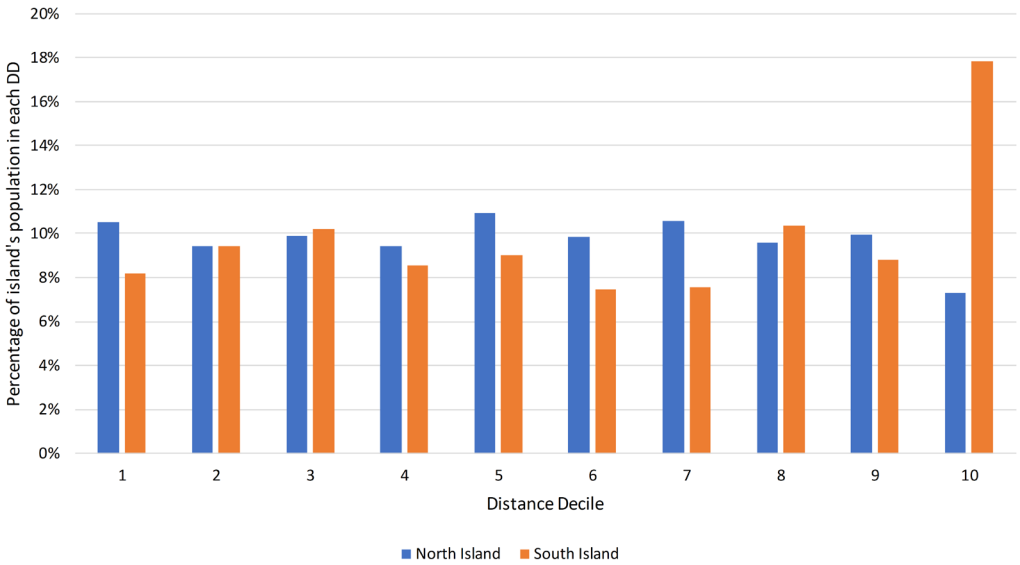
The outstanding difference is the proportion of enrollees in distance decile 10: 18% in the South Island and 7% in the North Island.

Distribution of health-related factors

Rurality and remoteness are not solely matters of distance: other factors can combine with distance in complex ways that need to be taken into account when providing health services and analysing health outcomes.

This section examines the spatial distribution in the analysis dataset of a number of factors known to be related to health outcomes: age, ethnicity and socioeconomic deprivation.[16] These factors vary according to distance decile, and the patterns of variation are quite different in the North and South islands. Accordingly, the patterns for each island are analysed separately and compared.

Figure 4: Distribution of validated PHO enrollees by distance decile in the North and South islands (March 2020).



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Age

Older age is associated with greater demand for health services. In the North Island, the proportion of enrollees aged 60 and over is clearly higher in distance deciles 9 (26%) and 10 (28%) than in deciles 1 to 8 (19% to 23%), whereas in the South Island the highest proportion is in decile 9 (29%), though the pattern is somewhat more variable. For most distance deciles, the 60+ proportion is higher in the South Island than the North Island. These patterns can be seen in Figure 5.

Ethnicity

Māori and Pacific Peoples tend to be less well served by the health system and tend to have poorer health outcomes and greater health needs.[1,16–19] The geographical distributions of the two groups are quite different. Figure 6 shows the percentage of validated PHO enrollees who are Māori in each distance decile for the two islands.

In the South Island, the Māori percentage trends slightly downward from distance decile 1 (11%) to 10 (8%). The Māori percentages are generally higher in the North Island and are particularly high in deciles 9 (22%) and 10 (32%).

Figure 7 shows the corresponding percentages for Pacific Peoples. The percentage of Pacific Peoples in each decile in the South Island shows a downward trend from decile 1 to 10, which is similar to the trend for Māori in the South Island. In the North Island, the highest percentages of Pacific Peoples (over 10%) are in distance deciles 1 to 6, which correspond to larger urban areas.

Deprivation

The socioeconomic deprivation of small areas or neighbourhoods can be measured using the New Zealand Index of Deprivation based on the 2013 census (NZDep2013).[20] Figure 8 shows the percentage of validated PHO enrollees in each distance decile who live in the most deprived areas (NZDep2013 deciles 9 and 10 or, equivalently, quintile 5).

In the South Island, the percentage in greatest deprivation is highest in distance deciles 1 to 4 (15% or higher), and very low in deciles 6 to 10 (5% or less). In contrast, in the North Island the percentage in greatest deprivation peaks in deciles 1 to 2 (30%) and decile 10 (33%).

Given the strong associations between distance decile and other factors known to be associated with variation in health outcomes, it should not be assumed that variation in health outcomes according to distance decile is due to distance in itself. Rather, the patient-centred spatial accessibility index provides a tool for distinguishing the effects of distance from the effects of other factors.

Figure 5: Percentage of validated PHO enrollees aged 60+ in each distance decile (March 2020).

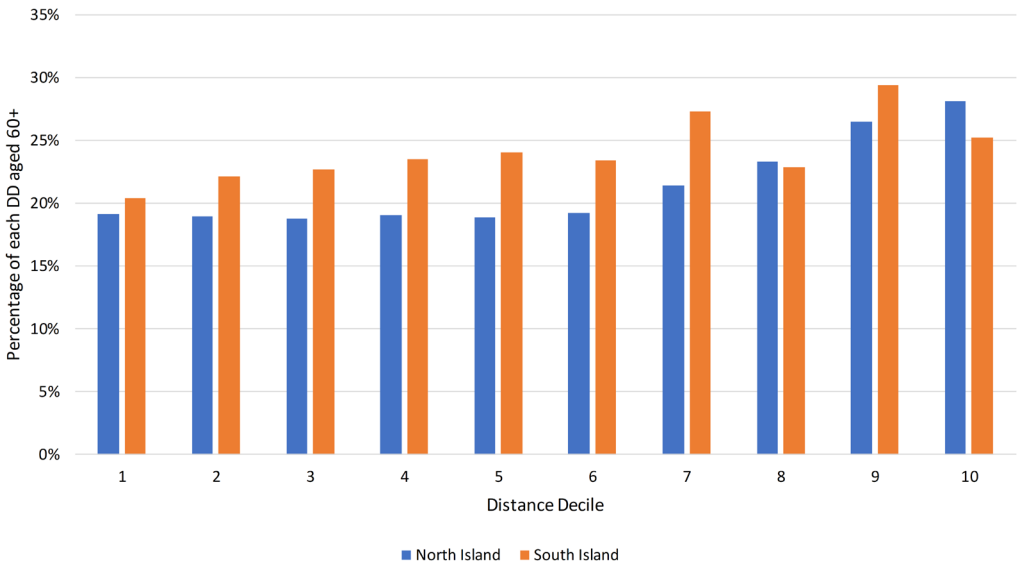

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Figure 6: Māori percentage of validated PHO enrollees in each distance decile (March 2020).

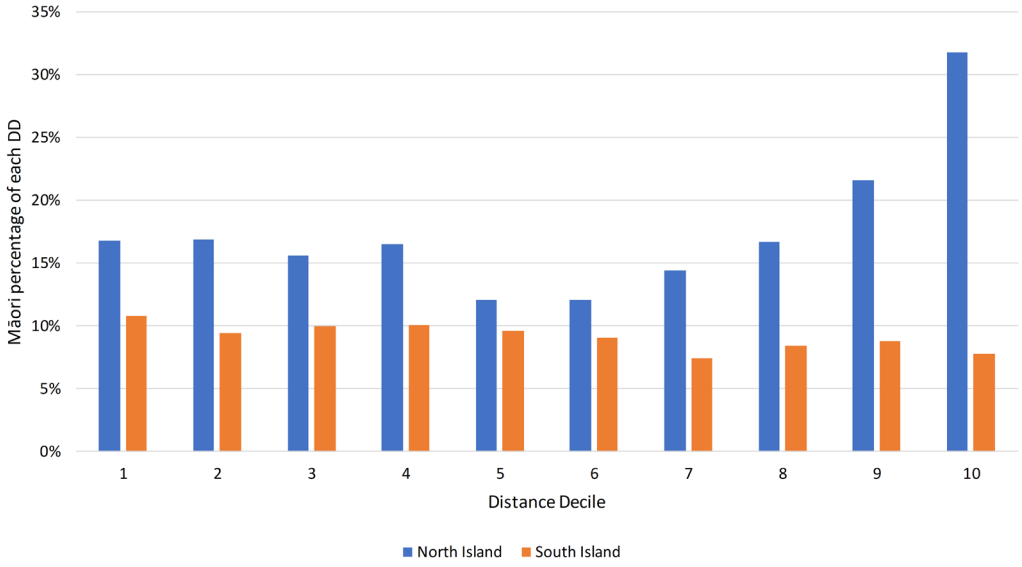
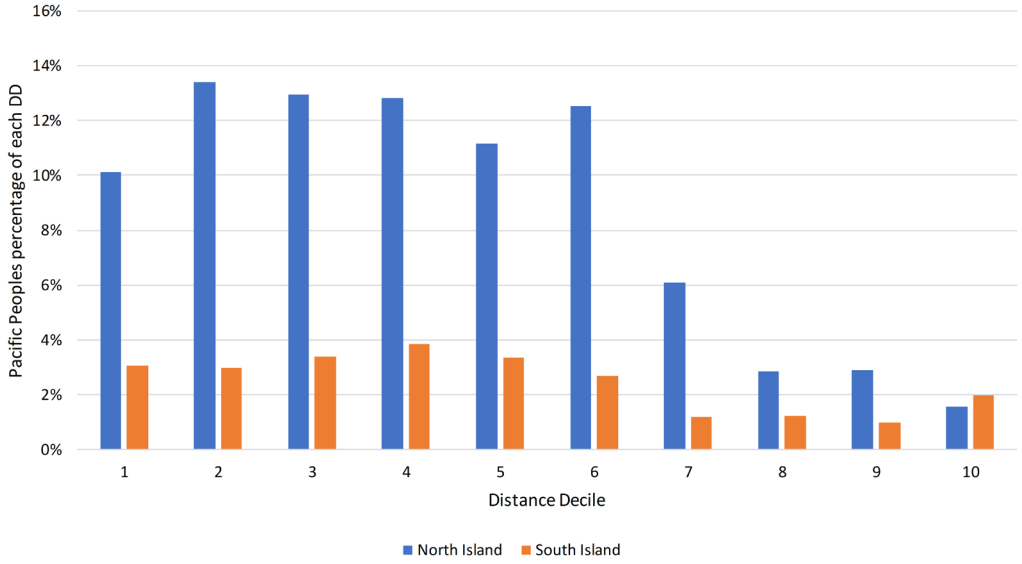


Figure 7: Pacific Peoples as percentage of validated PHO enrollees in each distance decile (March 2020).



Discussion

Limitations

One of the major limitations of the patient-centred health services spatial accessibility index (PCHSSAI) is the use of straight-line distance as an indicator of relative distance, rather than actual road distances or travel times. Another limitation is that the analysis applies to validated PHO enrollees rather than the total population: 6% of New Zealand residents are not enrolled with a PHO. Non-enrollees are more likely than enrollees to be aged 15 to 24, to live in the Auckland District Health Board area, to be Māori and to live in areas of higher deprivation.[21] It is not clear how these disparities might affect the overall distribution of distance scores if non-enrollees were to be included in the analysis. Furthermore, the analysis reported here is based on a single snapshot in time: we have not investigated seasonal or other temporal variation in enrollees' locations.

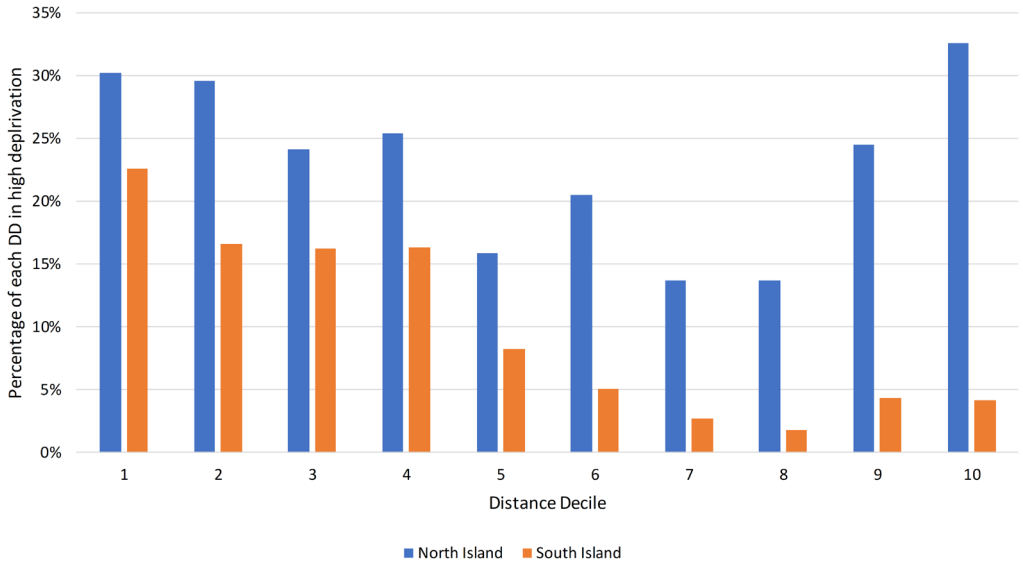
Comparison of approaches to urban, rural and remote health

The PCHSSAI is by design a narrowly focused measure of just one aspect of health care accessibility, namely patients' spatial distances from healthcare facilities. In this respect it resembles the revised Accessibility/Remoteness Index of Australia (ARIA+),[22–24] which is based on road distances to urban areas where various services, including health services, are located. Like ARIA+, the PCHSSAI is neither tied to any particular geographical classification nor complicated by considerations of population density but on the other hand, locations with the same score can have quite different characteristics: in the case of the PCHSSAI, locations with large distance scores (distance decile 10) can be in uninhabited wilderness or in bustling urban areas.

Like ARIA+ and the Index of Relative Rurality (IRR) developed in the United States,[25] the PCHSSAI provides a continuous numerical scale, which is an advantage from the point of view of statistical analysis and modelling. In addition, the PCHSSAI provides distance scores that can be matched to demographics and health outcomes at the individual patient level, which affords precision and flexibility in analysis and modelling.

The new Geographic Classification for Health (GCH)[7,26] is a modified version of Stats NZ's urban accessibility classification (UA). There are a number of differences

Figure 8: Percentage of validated PHO enrollees in greatest deprivation (NZDep 2013 deciles 9 and 10) in each distance decile (March 2020).



in methodology between the UA and the PCHSSAI approach. The UA is based on distances between areas, namely a SA1 (Statistical Area 1, a small geographical area with 100–200 residents,[27] measured from a central point) and a boundary of a larger urban area, whereas the PCHSSAI is based on the point-to-point distance between each enrollee's location and the locations of health facilities. On the other hand, the UA uses driving times which provide a more realistic measure than the straight-line distances used to calculate the PCHSSAI, and the PCHSSAI is not directly translatable into driving times. The UA is based on five-yearly census data, although it could be updated on the basis of population projections for SA1s (reflecting urban growth), which will start to be available from late 2021. The PCHSSAI has so far been updated on an annual basis but, in theory, could be constructed at any time, so that it could be updated six-monthly or quarterly. Unlike the UA, the PCHSSAI is health-specific: for example, if a hospital is upgraded to secondary status, then the PCHSSAI can be updated to take account of the changed healthcare environment.

The basic PCHSSAI methodology can also be adapted to measure accessibility to different types of health service: we have constructed another version based on distances to hospital emergency facilities (as well as primary care facilities) to analyse emergency presentations. The methodology could be adapted to include other types of health service, such as pharmacies and oral health services, as in Hobbs, Tomintz and Kingham's geographic analysis of child ambulatory sensitive hospitalisation (ASH) rates.[28]

Spatial accessibility and health outcomes

The PCHSSAI is not an end in itself. Rather, it is a tool for analysing health provision and health outcomes. We have analysed ASH rates for children aged 0–4 and found that these rates decline steadily from distance decile 1 to distance decile 10, in line with Hobbs, Tomintz and Kingham's[28] findings. Both sets of findings raise a question for further research as to whether this pattern is due at least in part to distance presenting a barrier to hospitalisation, or whether rural and remote primary practices provide more effective care of such children, or both.

The PCHSSAI is the basis of graphs published by the Rural General Practice Network[29] that compare mortality rates stratified by age in urban (distance deciles 1–8) and rural/remote areas (distance deciles 9–10) and highlighted higher age-specific mortality rates in rural/remote areas compared with urban areas. However, further analysis (at the individual patient level) has indicated that the overall difference between these urban and rural/remote rates can be largely accounted for by an overall difference in mortality rates between Māori and non-Māori and the greater proportion of Māori in some rural/remote areas, as noted above. This may indicate a need for more effective health services in those rural/remote areas which have relatively high Māori populations.

Conclusion

Distance score and distance decile provide an approach to rurality and remoteness that is based on where patients are rather than just where healthcare facilities are. They directly measure patients' relative spatial access to key healthcare facilities, namely secondary/tertiary hospitals and primary care practices.

With respect to Stats NZ's standard population-based urban-rural indicator (IUR 2020), the distance decile analysis indicates that the areas that Stats NZ labels "small urban areas" largely show the same low level of access to health services as the areas labelled "rural settlements" and "rural other."

Stats NZ's urban accessibility classification groups small urban areas with rural and remote areas as its starting point and then classifies these areas on the basis of distance to larger urban areas. It is thus conceptually similar to the patient-centred health services spatial accessibility index approach, and in practice there is a considerable amount of agreement between the two. This agreement provides an initial validation of our patient-centred health services spatial accessibility index as a tool for investigating rurality and remoteness in health services and health outcomes.

Distance deciles 9 and 10 correspond to the most rural and remote areas (including some remote urban areas) and are asso-

ciated with different health-related factors in the South and North islands. In the South Island, there is a particularly high proportion of PHO enrollees aged 60 and over in these distance deciles, whereas in the North Island, distance deciles 9 and 10 are characterised by high percentages of enrollees aged 60 and over, of Māori and of enrollees living in highly deprived areas, in line with the disadvantaged groups identified in a previous study of geographical access to emergency care.[5] Thus in both islands in distance deciles 9 and 10 there are factors indicating high healthcare needs that are likely to be exacerbated by difficulties of spatial access to healthcare facilities, especially secondary or tertiary hospitals.

Author contributions

The original concept and design of the index was formulated by EJ, coding and data matching was conducted by KM, summary and analysis was conducted by CL, writing the original manuscript was shared by EJ, CL and FX, and all co-authors contributed to revising the manuscript.

Appendix

Appendix Figure 1: Secondary/tertiary hospitals.

District health board	Hospital
Northland	Whangārei Hospital
Waitematā	North Shore Hospital Waitākere Hospital
Auckland	Auckland City Hospital
Counties Manukau	Middlemore Hospital
Waikato	Waikato Hospital
Lakes	Rotorua Hospital
Bay of Plenty	Tauranga Hospital Whakatāne Hospital
Hauora Tairāwhiti	Gisborne Hospital
Hawke's Bay	Hawke's Bay Hospital
Taranaki	Taranaki Base Hospital
MidCentral	Palmerston North Hospital
Whanganui	Whanganui Hospital
Capital and Coast	Wellington Hospital
Hutt Valley	Hutt Hospital
Wairarapa	Wairarapa Hospital
Nelson Marlborough	Nelson Hospital Wairau Hospital
West Coast	Greymouth Base Hospital
Canterbury	Christchurch Hospital
South Canterbury	Timaru Hospital
Southern	Dunedin Hospital Southland Hospital

Competing interests:
Nil.
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