# COVID-19 test sites in Victoria approaching Stage 4 restrictions: evaluating the relationship between remoteness, travel time and population serviced

Ali Lakhani,[1,2] Dennis Wollersheim[1]

## Abstract

**Objective**: In Australia, people residing remotely typically experience increased travel time to health services, and remote health services often have unfavourable population-to-provider ratios. The state of Victoria was treated as a case study and a spatial analysis investigated the impact of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) point-of-care-test (POCT) site location (Major City, Inner Regional or Outer Regional) on the mean travel time for closest residents and the number of closest residents.

**Methods**: A network analysis established the travel time from every mesh block in Victoria to the closest POCT site. Inferential analyses investigated the impact of POCT site location on travel time and the number of closest residents.

**Results**: Compared to urban locations, the mean travel time for closest residents to rural POCT sites was significantly higher, while rural POCT sites had significantly fewer residents to service.

**Conclusions**: Findings confirm Australian health service literature suggesting that rural regions have poorer proximate availability of health services, while also contrasting to literature indicating that Australian rural regions have fewer health services per capita.

**Implications for public health**: Localities within outer regional Victoria are candidates for a localised response to reduce unnecessary travel. Employing innovative service models may improve health service access and use and reduce population-to-provider ratios in rural locations.

**Key words**: GIS, COVID-19, point-of-care-testing, rural, health services

The World Health Organization declared the novel coronavirus (COVID-19) a global pandemic on 11 March 2020.[1] As of 2 February 2021, more than 100 million people have contracted the virus across 192 countries and nearly 2.5 million people have died as a result.[2] Diverse public health approaches to contain or reduce the spread of the virus have included individual social distancing[3-5] and preventing intercountry and within-country movement.[6,7] Certainly, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) point-of-care-testing (POCT) sites – sites where incidences of the virus can be confirmed – have a vital role in managing and hopefully reducing the spread.[8] At a basic level, identifying people who have the virus can ensure that quarantine policies are adhered to and broader social distancing measures are implemented.

A considerable body of spatial research has amassed over a very short period to answer practical questions pertaining to COVID-19. Initially, a seminal foundation article, conducted by Kamel Boulos and Geraghty[9] presented diverse ways that geographic information system (GIS) methods have been used and could be used in light of COVID-19. Their article confirmed that under the context of COVID-19, GIS methods have been useful towards identifying: i) the spread of the virus; ii) the spread of misinformation; and iii) individual close contacts to the virus. Furthermore, they also clarified that GIS methods could help to identify sites for services and support health service supply chain efforts. A review conducted by Franch-Pardo et al.[10] investigated the extent of peer-reviewed COVID-19 spatial research published between January and May 2020. Of the 63 sources reviewed, studies used spatial methods towards the stated domains: spatiotemporal analysis, health and social geography, environmental variables, data mining, and web-based mapping.

The equitable distribution of essential health services is an important public health issue.[11] In Australia, it has been confirmed that, compared to people in high service areas, people who experience a poorer availability of primary care report lesser use, while spending longer times in hospital.[12] High service areas fit the category of 'highly accessible' areas based on the Accessibility and Remoteness Index of Australia (ARIA).[12] The ARIA defines highly accessible areas as generally having unrestricted access to a range of goods and services and opportunities for social interaction (for a better description of the methodology

*1. School of Psychology and Public Health, La Trobe University, Victoria*
*2. The Hopkins Centre, Menzies Health Institute Queensland, Griffith University, Queensland*
**Correspondence to:** Dr Ali Lakhani, The School of Psychology and Public Health, La Trobe University, Room 3.06, 360 Collins Street, Melbourne, VIC, 3000; e-mail: a.lakhani@latrobe.edu.au
Submitted: February 2021; Revision requested: April 2021; Accepted: July 2021
The authors have stated they have no conflicts of interest.

*Aust NZ J Public Health.* 2021; 45:628-36; doi: 10.1111/1753-6405.13154

used to calculate the ARIA please see the Department of Aged Care[13]). Understandably, COVID-19 POCT sites are an essential health service[8] and it is important that testing sites are proximately available and have the capacity to meet demand.[14] Of the 63 sources identified within the review by Franch-Pardo et al.,[10] no study used spatial methods to identify the availability of COVID-19 testing sites for priority populations. Similarly, Kost[14] reviewed the extent of geospatial research focusing on POCT sites for Ebola and coronavirus and their review also yielded zero studies where spatial methods have been used to ascertain the availability of COVID-19 POCT sites. To the knowledge of the authors, two recent US-based studies have investigated the geographic distribution and racial disparity of POCT sites within the states of Florida[15] and Massachusetts.[16]

The authors uphold the opinion that investigating the geographic dispersion of COVID-19 POCT sites in Australia is an important public health issue. To date, Australian centric spatial research has yet to address this objective; rather, it has investigated the proximity of essential health services (for example hospitals and/or palliative care services) in relation to priority populations.[17,18]

As Australia is characterised as having populations concentrated in urban centres with vast areas that are sparsely populated,[19] clarifying the distribution of services in relation to population while accounting for remoteness is an important endeavour[20] (particularly for pandemic response planning[21]). Such research can clarify areas that are under-serviced and support the location planning of POCT sites and – broadly – the location planning of essential health services.

### The current study

A paucity of research has used spatial methods to investigate the geographic distribution of COVID-19 POCT sites with the aim of clarifying the impact of remoteness on travel time and the potential population being serviced. Similar to previous health service research,[22-24] it is hypothesised that, compared to urban areas, remote areas experience higher travel times to the closest POCT site and thus a relatively poorer proximate availability. While in relation to number of people serviced, it is hypothesised that, compared to POCT sites in urban locations, there would be a higher number of people serviced per rural POCT site, given research suggesting that there are either comparable or fewer health services per capita in Australian rural locations[25-27] and that rural regions generally have poorer access to health services.[28] Consequently, the state of Victoria, Australia, was treated as a case study and these issues were investigated. The study aimed to answer the following questions:

1. What is the impact of POCT site location (Major Cities in Victoria, Inner Regional Victoria or Outer Regional Victoria) on the mean travel time for residents who were closest to the site (based on travel time)?
2. What is the impact of site location on the number of closest residents for each POCT site?

The state of Victoria was identified as an opportune region for this case study given a recent increase of cases compared to other Australian states. From mid-April 2020 onward, most states and territories in Australia were identifying relatively few cases daily.[29] Consequently, social distancing policies were being amended, and services and spaces across the country were opening up (please refer to Roadmap to Easing Queensland Restrictions[30] and the COVID-19 coronavirus: Western Australia Roadmap[31] for example timelines of when social distancing restrictions were being lifted). For the state of Victoria, the reduction in cases was brief, and cases began to increase towards the end of June 2020.[32] These cases were primarily in metropolitan Melbourne (see the Department of Health and Human Services 2020 Restricted Activity Directions[33] for details of Local Government Areas that comprise metropolitan Melbourne) and Mitchell Shire. Government responded by initiating Stage 3 restrictions in metropolitan Melbourne as of 11:59pm on 8 July 2020,[34] and declared Victoria under a 'state of disaster' with Stage 4 restrictions on 2 August 2020.[35] POCT was increased throughout the stated period with the intention of ensuring that people within the state had access to a facility.

## Methods

### Data sources

Data sources included the Australian Bureau of Statistics (ABS) and the Victoria State Government Department of Health and Human Services (DHHS). The Australian Statistical Geography Standard (ASGS) Remoteness Structure,[36] an ABS Statistical Area 1 (SA1) shapefile[37] and mesh block shapefile[37] were collected from the ABS. Australia uses a five-tier remoteness structure consisting of the following classifications: Major Cities in Australia, Inner Regional Australia, Outer Regional Australia, Remote Australia, and Very Remote Australia.[36] The ASGS 'Main Structure' also includes a seven-tier geographical standard for providing ABS economic and demographic data.[36] Mesh blocks and SA1s are the smallest geographical areas for which demographic information is provided.[37] Further information around these classifications is available via the ABS.[37] Finally, the number of people residing in each mesh block within Victoria was downloaded from the ABS.[38] The State Government of Victoria DHHS maintains an up-to-date list of COVID-19 testing sites. For this study, the locations of all COVID-19 POCT sites identified on 24 July 2020 were considered.[39]

### Data analysis

All data were analysed using a combination of R [40], IBM's SPSS [41] and ESRI's ArcMap 10.7.1.[42]

### Spatial analysis

All network analyses and calculations were conducted via R.[40,43] A geographically weighted centroid (a marker generally representing the centre of a geographic area) was placed within each mesh block and the travel time was calculated via the Open Source Routing Machine.[44] Specifically, the shortest travel time via motor vehicle on public roads from each Victorian mesh block centroid to a POCT site was established. The OpenStreetMap road network[45] was used (accessed on 24 July 2020). Previous research has found that OpenStreetMap in Australia is precise and accurately covers 94% of the Australian road network.[46] For each POCT site, the following information was calculated for the closest mesh blocks (based on travel time): i) the average travel time; ii) the total population; and iii) the average Index of Relative Socio-economic Disadvantage (IRSD)[47] score. Additionally, the regional classification of the POCT site location was established. All maps were produced via ArcMap 10.7.1.[42] Relevant code[48] and data[49] are available for download.

### Inferential analysis

Data from all spatial analyses were exported to IBM's SPSS. The distribution of the mean travel time for closest residents to each service and the number of closest residents for each service was established by Shapiro-Wilk tests for normality. The distribution of both outcomes aligned with POCT sites across the three regional classifications (Major Cities in Victoria, Inner Regional Victoria, and Outer Regional Victoria) was non-normal. In terms of mean travel time to each service for closest residents, Shapiro-Wilk test coefficients were (significant *p*-values are indicative of a non-normal distribution): $W$=0.681, $p$<0.001 (Major Cities in Victoria); $W$=0.932, $p$<0.05 (Inner Regional Victoria); and $W$=0.893, $p$<0.05 (Outer Regional Victoria). Comparably, specific to closest residents, Shapiro-Wilk test coefficients were: $W$=0.878, $p$<0.001 (Major Cities in Victoria); $W$=0.743, $p$<0.001 (Inner Regional Victoria); and $W$=0.828, $p$<0.05 (Outer Regional Victoria). As a result, non-parametric inferential analyses were progressed. Kruskal-Wallis H tests were undertaken to establish if significant differences in mean travel time for closest residents and the number of closest residents for each POCT site existed between sites across the three regional classifications. Where a significant difference was apparent, pairwise comparisons by means of the Mann-Whitney U test statistic were progressed to establish where differences existed.

Furthermore, the distribution of IRSD values for closest mesh blocks was non-normal for POCT sites within Major Cities in Victoria ($W$=0.926, $p$<0.001); while normal for POCT sites within Inner Regional Victoria ($W$=0.981, $p$=0.787) and Outer Regional Victoria ($W$=0.948, $p$=0.400). To better contextualise study findings and establish how socioeconomic status may also impact access to POCT sites, the effect of regional classification on IRSD was initially tested via a Kruskal-Wallis H test, and Mann-Whitney U tests were conducted to establish where significant differences existed. Spearman's rank-order correlations were used to investigate the association between the mean IRSD for closest mesh blocks for each POCT site, mean travel time for closest residents and the number of closest residents for each POCT site.

## Results

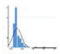
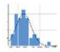
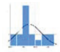
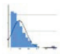
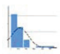
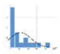
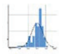
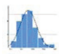
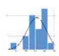
There were 156 POCT sites on 24 July 2020 located across the following regional classifications (with number of sites in brackets): Major Cities (96), Inner Regional (42) or Outer Regional (18). Table 1 details the site categories within each regional classification.

Table 2 provides descriptive statistics for travel time to a POCT site for closest residents, the number of closest residents for a COVID-19 POCT site and the mean IRSD value for closest mesh blocks to each testing site across the three regional classifications. Figure 1 is a scatterplot that clarifies the mean travel time and the number of closest residents for POCT sites within each regional classification. Figure 2 illustrates the travel time from each mesh block to the closest POCT site (the Melbourne area is illustrated in Figure 2). Within Figure 3, each POCT site is represented by a blue circle, where the size of the blue circle represents the mean travel time for closest residents (the Melbourne area is illustrated in Figure 4). Similarly, in Figure 5, each POCT site is represented by a blue circle, where the size of the blue circle represents indicates the number of closest residents (the Melbourne area is illustrated in Figure 6). In Figure 7, each POCT site is represented by a blue circle, where the size of the blue circle represents IRSD (the Melbourne area is illustrated in Figure 8).

**Table 1: Testing site categories and regional classification.**

| Regional Classification | Number/ Percent | GP Respiratory Clinic | Hospital Respiratory Clinic | Community Health Respiratory Clinic | Pathology Collection Centre | Walk-through Testing Facility | Drive-through Testing Facility |
|---|---|---|---|---|---|---|---|
| Major Cities | Number | 12 | 16 | 9 | 25 | 9 | 25 |
| | Percent | 12.5% | 16.7% | 9.4% | 26.0% | 9.4% | 26.0% |
| Inner Regional | Number | 11 | 28 | 2 | 1 | 0 | 0 |
| | Percent | 26.2% | 66.7% | 4.8% | 2.4% | 0.0% | 0.0% |
| Outer Regional | Number | 4 | 8 | 1 | 1 | 3 | 1 |
| | Percent | 22.2% | 44.4% | 5.6% | 5.6% | 16.7% | 5.6% |
| Total | | 27 | 52 | 12 | 27 | 12 | 26 |

**Table 2: Descriptive statistics for outcome variables.**

| | Min | 25th Percentile | Median | 75th Percentile | Max | Histogram |
|---|---|---|---|---|---|---|
| Travel Time (Rounded in Minutes) | | | | | | |
| Major Cities | 2 | 4 | 5 | 7 | 31 |  |
| Inner Regional | 3 | 10 | 16 | 23 | 52 |  |
| Outer Regional | 2 | 20 | 23 | 47 | 66 |  |
| Population (Number of People) | | | | | | |
| Major Cities | 180 | 22,392 | 39,184 | 66,418 | 234,777 |  |
| Inner Regional | 524 | 15,177 | 20,743 | 37,366 | 127,979 |  |
| Outer Regional | 313 | 3,192 | 6,168 | 18,502 | 40,797 |  |
| IRSD | | | | | | |
| Major Cities | 782 | 970 | 1020 | 1046 | 1106 |  |
| Inner Regional | 904 | 950 | 976 | 1003 | 1082 |  |
| Outer Regional | 888 | 950 | 963 | 991 | 1011 |  |

The median travel time for closest residents to POCT sites located in Major Cities in Victoria was the least while the number of residents closest to these sites was the greatest, while median travel time was longest and number of residents lowest for POCT sites located in Outer Regional Victoria. Two Kruskal-Wallis H tests confirmed that significant differences in mean travel time to a POCT site for closest residents ($X^2[2]=69.20$, $p<0.001$) and the number of closest residents ($X^2[2]=27.93$, $p<0.001$) between sites across the three regional classifications existed. Mann-Whitney U tests confirmed that significant pairwise differences existed across both outcomes. The mean travel time for residents closest to POCT sites located in Major Cities in Victoria was significantly lower than residents closest to POCT sites in Inner Regional Victoria (U=440.00, $p<0.001$) and Outer Regional Victoria (U=177.00, $p<0.001$). Compared to residents closest to POCT sites in Outer Regional Victoria, residents closest to POCT sites in Inner Regional Victoria experienced significantly shorter travel times (U=207.00, $p<0.05$). POCT sites in Major Cities in Victoria had a significantly higher number of closest residents compared to POCT sites in Inner Regional Victoria (U=1336.00, $p<0.05$) and Outer Regional Victoria (U=273.00, $p<0.001$). POCT sites in Inner regional Victoria had a significantly higher number of closest residents compared to POCT sites in Outer Regional Victoria (U=179, $p<0.05$). In summary, all pairwise comparisons confirmed that: i) the number of closest residents for a POCT site reduced as remoteness level increased; and ii) the travel time for closest residents to the closest POCT site increased as remoteness level increased.

Figure 1: Travel time and number of closest residents.

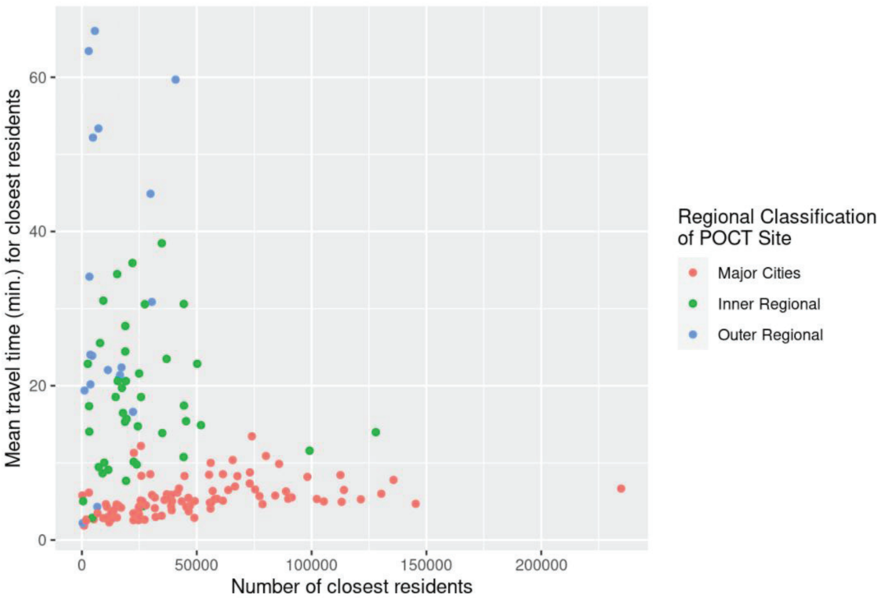
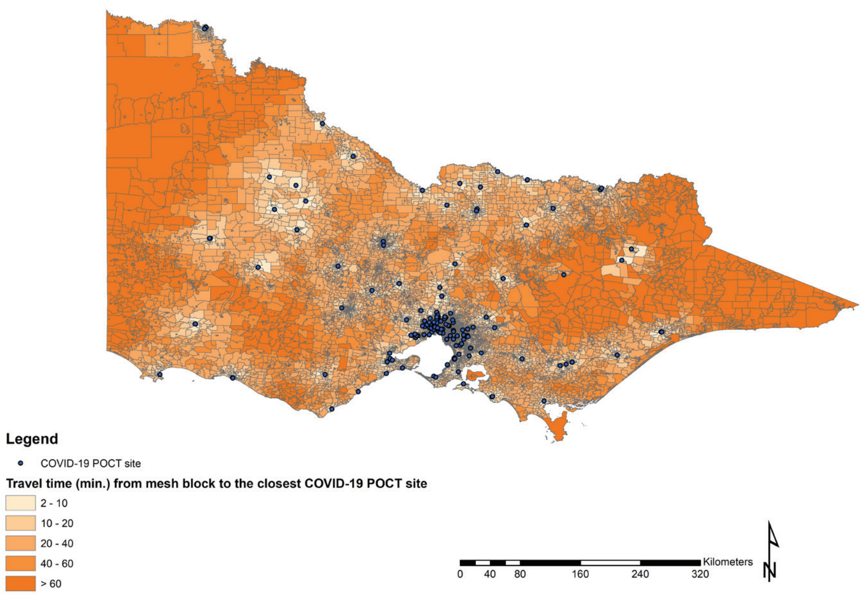



Figure 2: Travel time for each mesh block to the closest POCT site.




The median IRSD was lowest for POCT sites in Outer Regional Victoria, while highest for POCT sites in Major Cities in Victoria. A Kruskal-Wallis H test confirmed that a significant difference in IRSD values for sites across the three regional classifications existed ($X^2[2]=18.53$, $p<0.001$). Mann-Whitney U tests confirmed that sites in Major Cities in Victoria had significantly higher IRSD values compared to sites in Inner Regional Victoria (U=1304, $p<0.05$) and Outer Regional Victoria (U=430, $p<0.05$). A significant difference in IRSD values between sites in Inner Regional Victoria and Outer Regional Victoria did not exist (U=300, $p=0.208$). Spearman rank-order correlations found significant associations between the mean IRSD value for closest mesh blocks to a POCT site and travel time for closest residents ($r_s=-0.228$, $p<0.05$), and number of closest residents ($r_s=0.279$, $p<0.001$). This suggests that people residing in areas with a lower socioeconomic status experience a longer travel time to the closest POCT site, while attending sites that serve fewer closest residents.

## Discussion

The hypothesis (informed by Australian centric health service access research[22-24]) that the closest residents to POCT sites located in urban locations would have a significantly lower travel time compared to closest residents to POCT sites in rural locations was upheld. While the hypothesis (also informed by Australian centric health service research[25,27]) that POCT sites in rural locations would have a greater number of people to service was not upheld. Over the suggested period, for the state of Victoria, rurality had an effect on the potential population being serviced by COVID-19 POCT sites, and the travel time that closest residents experienced. Where the closest testing site was in Outer Regional Victoria, end users experienced significantly longer travel times compared to end users who had a closest testing site in Inner Regional or Major Cities in Victoria. Similarly, where the closest testing site was in Inner Regional Victoria, end users experienced significantly longer travel times compared to end users who had a closest testing site in Major Cities in Victoria. In relation to the number of closest residents, compared to testing sites in Inner Regional and Outer Regional Victoria, testing sites in Major Cities in Australia had a significantly higher number of closest residents. Similarly, compared to testing sites in Outer Regional Victoria, Inner Regional Victoria had a significantly higher number of closest residents.

Figure 3: Travel time for each mesh block within greater Melbourne.

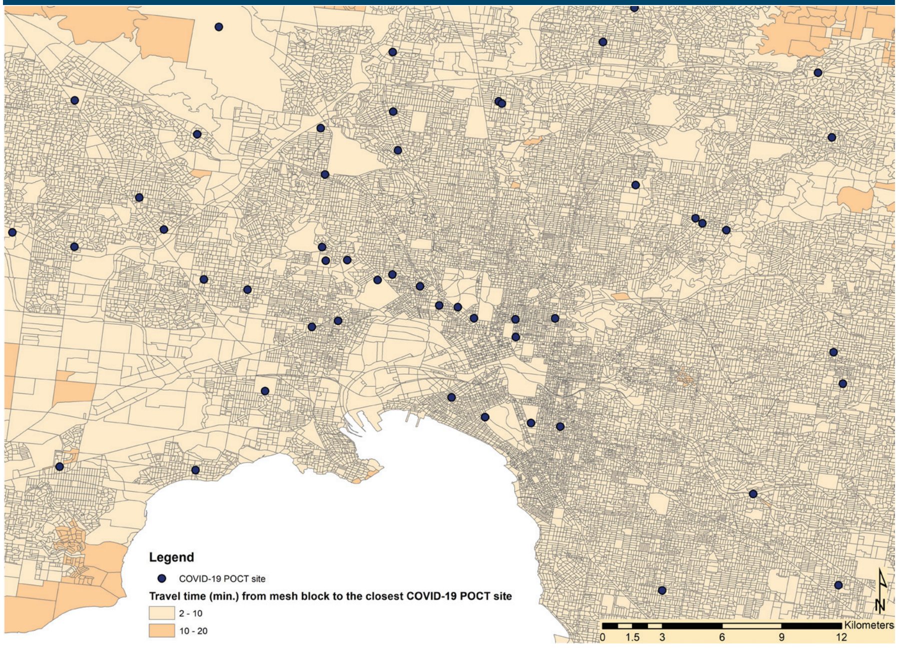
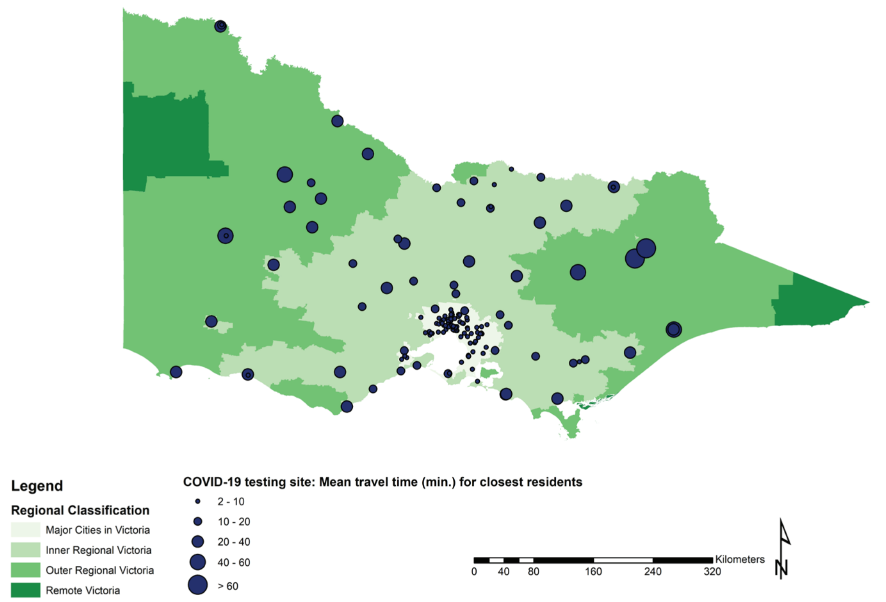



Figure 4: Mean travel time for closest residents.




The findings from this study align with a considerable body of literature surrounding the proximate availability of health services for people in rural and/or remote locations.[23,50] For example, Mu, Chen and Zhen[50] investigated the travel time to Supplemental Nutrition Assistance Program offices for localities across the US. Their findings confirmed that for every 10 percentage point increase in rurality, travel time to the closest office increased by one minute. Similarly, in their Australian-specific study, Coffee et al.[22] considered the availability that all localities in Australia had to cardiac services and developed a cardiac service accessibility index. Their findings confirmed that localities within rural and remote Australia experienced the longest travel times and had the poorest availability of cardiac services. Similar findings have been confirmed by Australian research focusing on disability[51] and the availability of hospitals.[52] By investigating the effect of remoteness on the travel time to COVID-19 POCT sites, the study adds knowledge to the area and confirms that, not surprisingly, testing sites are another health service type where residents of remote localities may experience an increased travel burden.

Travel has been identified as a factor that has a considerable impact on an individual's receipt of health services.[53] The significantly longer travel times that people in remote localities within Victoria experienced to visit a COVID-19 POCT site during the time in question could have hindered the use of such sites. An evidence-based review conducted by Syed, Gerber and Sharp[54] confirmed that travel barriers – including distance – hinder health service use (subsequent to their review, this finding has been confirmed[55]). Despite the severity of COVID-19 and the recognition that swift response is needed, under the current context, people in rural and remote Victoria with poor proximate POCT site availability may have decided to forgo being tested. (This point can only be confirmed by retrospective research.) This could have had an adverse impact on individual and community health outcomes.

The findings from this research also add to our understanding of the impact of geography on access to health services within Australia. Generally, Australian research has confirmed that, compared to urban regions, the number of health services per capita is lesser for those in rural regions[25-27] and that rural regions generally have poorer access to health services.[28] These findings suggest that, compared to those in urban areas, rural services may need to provide service to a larger pool of people. In contrast, the findings from this study confirmed that, compared to urban regions, POCT services located in Outer Regional Victoria had significantly fewer closest residents (indicative of them having to service a lesser number of people). The findings suggest that rural POCT sites for COVID-19 may not experience comparable service demand issues to other rural health services, and thus may have a better capacity to support rural locations. Furthermore, a similar relationship may exist throughout rural regions across other Australian states. The absence of rigorous research in this area makes it difficult to confirm if both points are accurate.

Finally, the findings from this study improve our understanding of the relationship between remoteness and disadvantage and how remoteness and disadvantage may impact access to health services. Findings confirmed that the mean IRSD for mesh blocks closest to a POCT site located within Major Cities in Victoria was significantly higher (indicative of experiencing advantage) than the mean IRSD for mesh blocks closest to a POCT site within Inner Regional or Outer Regional Victoria. This finding is not surprising and aligns with national research confirming that remote areas in Australia experience higher levels of disadvantage.[56] (However, this finding adds knowledge to the area as it affirms that significant differences in socioeconomic status between mesh blocks proximate to health services across regional classifications in Australia exist). A negative association between mean IRSD for closest mesh blocks to a testing site and mean travel time to the closest POCT site was found, suggesting that those with a higher socioeconomic status experienced lower travel time and had favourable access to the nearest POCT site. Clearly, during the time of data collection, a socioeconomic disparity in access to POCT existed, where those residing in Major Cities in Victoria and experiencing advantage (relative to Inner Regional and Outer Regional Victoria) had better access to sites. It is important for future research to investigate if this disparity exists for diverse health services.

**Figure 5: Mean travel time for closest residents within greater Melbourne.**

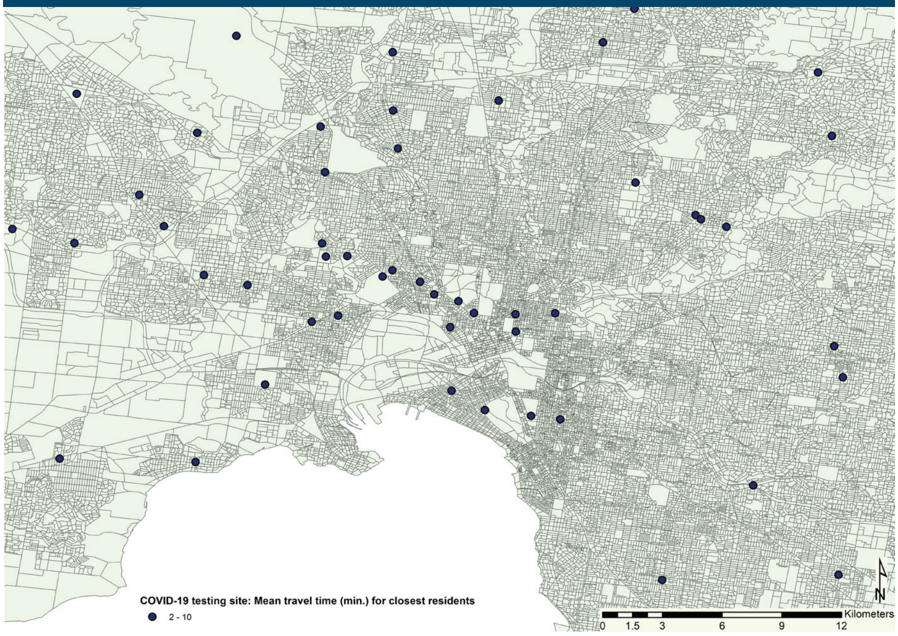
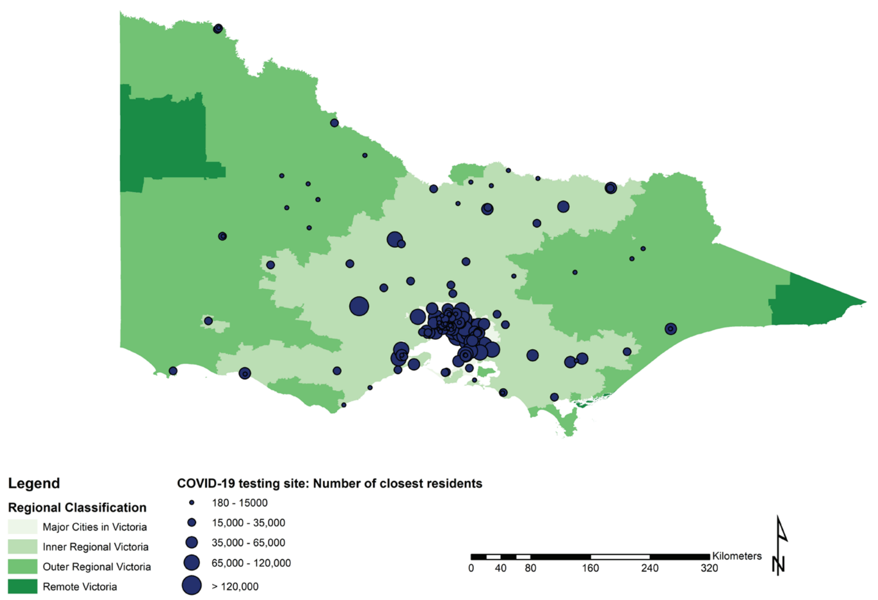



**Figure 6: Number of closest residents.**




## Implications

It may be worthwhile to apply the models used to identify POCT sites within Victoria towards the identification of other essential health service locations. (Under the context of COVID-19, applying models used to identify POCT sites in Victoria might be worthwhile towards the identification of vaccination hubs within remote Victoria.) Rethinking the locations of rural and remote health services may help to address potential capacity issues that specific services face. In this respect, given Australian Institute of Health and Welfare[27] health workforce data, considering alternative locations for allied health and dental health services across rural Australia could be prioritised, as the greatest rural and urban discrepancies in population-to-provider ratios exist for these services.

These findings may also have implications for health service location provision (beyond POCT sites) within Australia, particularly within states and territories where a high percentage of the population resides in outer regional and/or remote locations (see, for example, the Northern Territory or Tasmania[57]). For these states and territories, it is important to establish if rural and remote health services mirror national trends of having poor population-to-provider ratios and if residential localities experience significantly longer travel times when compared to those who reside closest to urban services. If poor ratios exist, it may be worthwhile to trial unique service delivery models. In this respect, localised responses should be developed and prioritised (a perspective that has already been advocated for in terms of service provision under the context of COVID-19[58]).

Innovative solutions are required to address the poor availability of specific health services (particularly allied health services) within rural and remote regions. One clear response is adopting a co-location model, where health services with poor availability are periodically co-located at an available health service within a remote and arguably underserviced region.[59,60] This delivery option is also termed the 'hub and spoke' model,[61] and has already increased the uptake of health services for at-risk populations within metropolitan Australia.[62] An ideal co-location site is the primary health service within a remote setting (for example, the general practitioner and/or community health centre). This approach has been employed in Australia; however, the extent of co-located services is limited. For example, in terms of general practitioner practices, co-located services largely include pathology centres and pharmacies.[63] Increasing the disciplines co-located – perhaps focusing on allied health disciplines where, compared to urban locations, rural locations have a poorer population to provider ratios[27] – may be beneficial and improve access to such health services for people in rural Australia.

Despite the potential for co-location as a delivery model to improve access and use, the provision of health services in rural Australia is in part hindered by the lack of a skilled workforce. Thus, it is important to establish and employ processes that can promote the active engagement of skilled health professionals within rural locations. One process is the Department of Health Medical Rural Bonded Scholarship (MRBS) Scheme,[64] where Commonwealth-supported medical school placements are provided to medical students who commit to work in a rural or remote area for six years after accreditation. Additional methods can be informed by factors that promote the recruitment and retention of health professionals in rural locations. In their review, Viscomi et al.[65] confirmed that living remotely during childhood, completing high school in a rural area, completing practitioner placements in a rural area and developing an understanding of rural health issues are all factors that contribute to the recruitment and retention of health professionals within rural locations. Interventions can be designed based on these factors. For example, offering scholarships and/or tailored education interventions for students in rural locations that encourage them to pursue health disciplines that are poorly provided in rural locations could be beneficial. Additionally, integrating medical training in rural locations through collaborations between universities and remote localities may improve potential practitioner knowledge of rural health issues while also allowing them to become acclimated to rural settings. Additional avenues to promote retention can relate to professional modifiable factors including professional mentoring, promotion and career pathways, and autonomy.[66]

**Figure 7: Number of closest residents within greater Melbourne.**

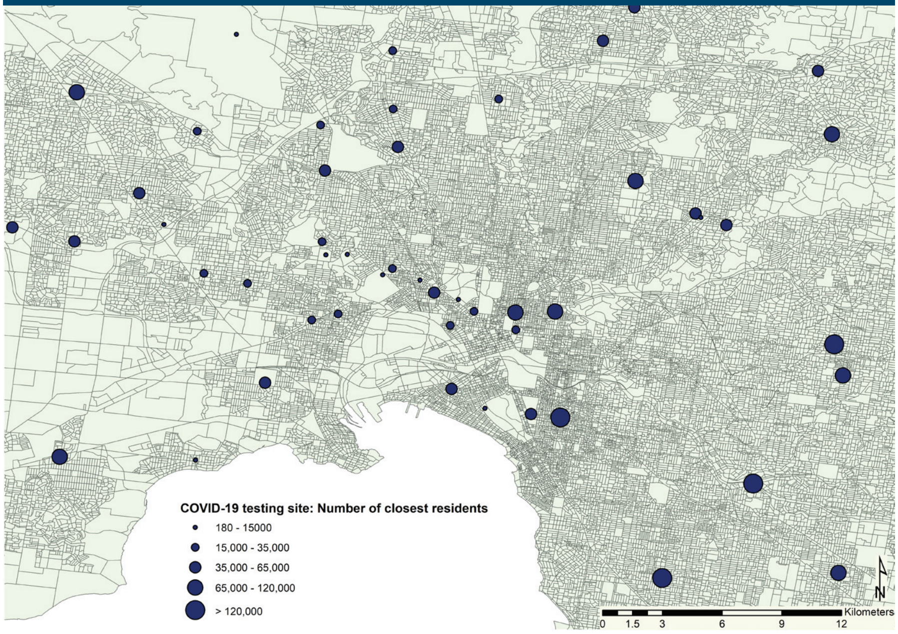
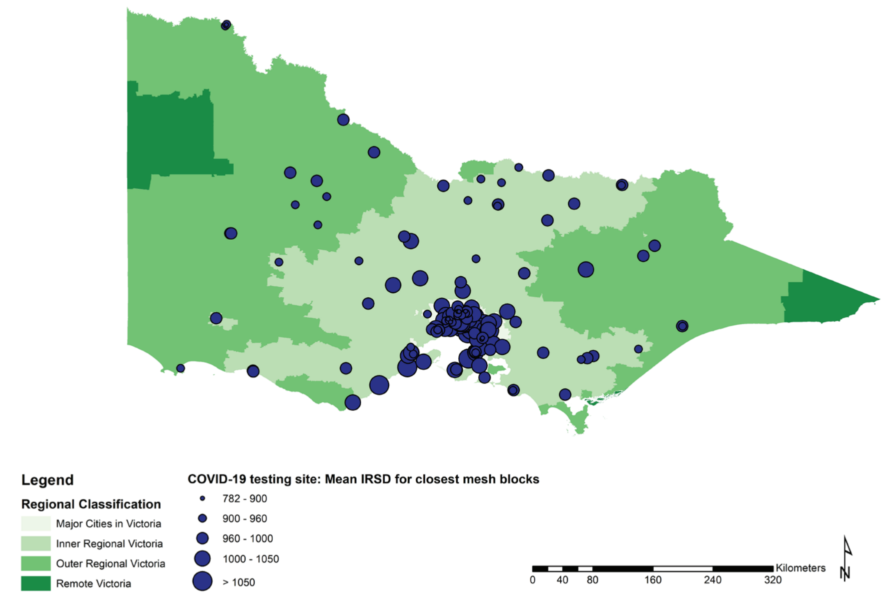


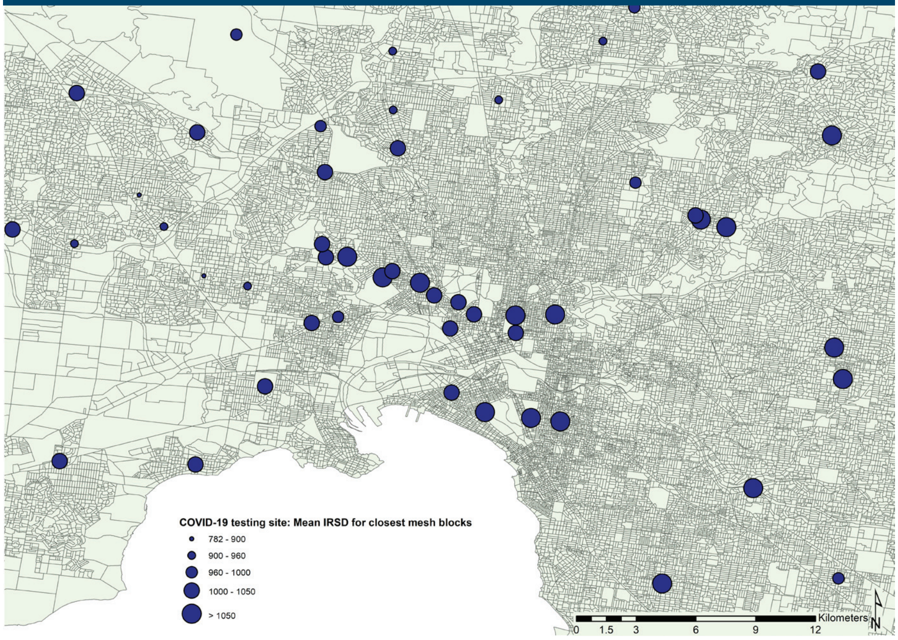

**Figure 8: Mean IRSD for closest mesh blocks to each POCT site.**




### *Limitations*

The study has limitations that are important to consider. First, the study investigates the distribution of COVID-19 POCT sites in Victoria during a moment in time, and spatial methods were used to establish if differences existed in travel times and population requiring service existed between those in urban and rural locations. Testing site locations were responsive to COVID-19 cases and positioned as a result; consequently, they were constantly being amended and perhaps later addressed travel

**Figure 9: Mean IRSD for closest mesh blocks to each POCT site within Greater Melbourne.**




gaps identified. Additionally, the study did not consider the geographic distribution of case numbers in relation to POCT sites as the research questions did not aim to establish the geographic distribution of sites in relation to active cases; rather they aimed to establish the geographic distribution of sites in relation to population. Finally, the study investigated the distribution of sites within a single state, and thus did not establish the impact of remoteness on the travel time to – and population serviced by – POCT sites across Australia.

## Conclusions

To the knowledge of the authors, this is one of the first studies globally where spatial methods have been used to clarify the geographic distribution of COVID-19 POCT sites. The findings highlight the impact of site location on travel time and potential client pool, and perhaps, health service use and service capacity. Health service site selection should be responsive to these issues and ensure that localised responses are consistently being developed. This is especially the case during the time of a pandemic, where travel outside of the community can contribute to the spread. The considerable travel times faced by people in outer regional Victoria may be experienced by people residing in rural and remote locations across other settings in Australia. Additionally, the inferior travel times experienced by those within rural and regional settings, coupled with potential socioeconomic disadvantage, may work to contribute to a disparity in health status between people residing in remote and urban settings. Consequently, it is important to ensure that there is an equitable distribution of health services, responsive to regional classification and socioeconomic status. Doing so may improve access to health services for those in remote settings who experience disadvantage. Further research is needed to establish localities within Australia that are underserviced. Such research can inform future local response efforts and also confirm whether or not the issue of poor accessibility moves beyond the case-study example provided.

## Acknowledgements

This research was funded by a La Trobe University, College of Science, Health and Engineering Start-Up Grant. The techniques used in this research draw on the Epidoros™ framework, first developed by Griffith University in 2008 in partnership with Metro South Health and Esri Australia with additional funding from the Australian Research Council and the Motor Accident Insurance Commission Qld. Dr Ali Lakhani would like to acknowledge that Professor Elizabeth Kendall has encouraged and advocated for the use of spatial methods in light of COVID-19.

## References

1. World Health Organization. *Rolling Updates on Coronavirus Disease (COVID-2019)* [Internet]. Geneva (CHE): WHO; 2020 [cited: 2020 Mar 29]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen
2. Johns Hopkins University Coronavirus Resource Centre. *COVID-19 Dashboard by the Center for Systems Science and Engineering - Global Cases* [Internet]. Baltimore (MD): JHU & Medicine; 2020 [cited: 2021 Feb 2]. Available from: https://coronavirus.jhu.edu/map.html
3. De Vos J. The effect of COVID-19 and subsequent social distancing on travel behavior. *Transp Res Interdiscip Perspect*. 2020;5:100121.
4. de Haas M, Faber R, Hamersma M. How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: Evidence from longitudinal data in the Netherlands. *Transp Res Interdiscip Perspect*. 2020;6:100150.
5. Park S, Kim B, Lee J. social distancing and outdoor physical activity during the COVID-19 outbreak in South Korea: Implications for physical distancing strategies. *Asia Pac J Public Health*. 2020;32(6-7):360-2.
6. Salcedo A, Yar S, Cherelus G. Coronavirus travel restrictions, across the globe. *The New York Times*. 2020; [Author: please provide the day and time the article was published.]
7. Abid K, Bari YA, Younas M, Tahir Javaid S, Imran A. Progress of COVID-19 epidemic in Pakistan. *Asia Pac J Public Health*. 2020;32(4):154-6.
8. Mashamba-Thompson TP, Drain PK. Point-of-care diagnostic services as an integral part of health services during the novel coronavirus 2019 era. *Diagnostics (Basel)*. 2020;10(7):449.
9. Kamel Boulos MN, Geraghty EM. Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: How 21st century GIS technologies are supporting the global fight against outbreaks and epidemics. *Int J Health Geogr*. 2020;19(1):8.
10. Franch-Pardo I, Napoletano BM, Rosete-Verges F, Billa L. Spatial analysis and GIS in the study of COVID-19. A review. *Sci Total Environ*. 2020;739:140033.
11. von Schuckmann LA, Smithers BM, Khosrotehrani K, et al. Use of support services in a sample of patients with high-risk primary melanomas in urban, regional and rural Queensland. *Aust N Z J Public Health*. 2017;41(3):315-19.
12. Eckert KA, Taylor AW, Wilkinson D. Does health service utilisation vary by remoteness? South Australian population data and the Accessibility and Remoteness Index of Australia. *Aust N Z J Public Health*. 2004;28(5):426-32.
13. Australian Department of Health and Aged Care. *Measuring Remoteness: Accessibility/Remoteness Index of Australia (ARIA)*. Canberra (AUST): Government of Australia; 2000
14. Kost GJ. Geospatial hotspots need point-of-care strategies to stop highly infectious outbreaks: Ebola and coronavirus. *Arch Pathol Lab Med*. 2020;144(10):1166-90.
15. Tao R, Downs J, Beckie TM, Chen Y, McNelley W. Examining spatial accessibility to COVID-19 testing sites in Florida. *Annals of GIS*. 2020;26(4):319-27.
16. Hu T, Yue H, Wang C, et al. Racial segregation, testing site access, and COVID-19 incidence rate in Massachusetts, USA. *Int J Environ Res Public Health*. 2020;17(24):9528.
17. Lakhani A. Which Melbourne metropolitan areas are vulnerable to COVID-19 based on age, disability, and access to health services? Using spatial analysis to identify service gaps and inform delivery. *Journal of Pain and Symptom Management*. 2020 Jul 1;60(1):e41-4.
18. Lakhani A. Introducing the percent, number, availability, and capacity [PNAC] spatial approach to identify priority rural areas requiring targeted health support in light of COVID-19: a commentary and application. *The Journal of Rural Health*. 2021 Jan;37(1):149-52.

19. Australian Bureau of Statistics. *3218.0 - Regional Population Growth, Australia, 2016-17* [Internet]. Canberra (AUST): ABS: 2018 [cited: 2021 Feb 2]. Available from: https://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/3218.0Main%20Features702016-17
20. Barr M, Duncan J, Dally K. A systematic review of services to dhh children in rural and remote regions. *J Deaf Stud Deaf Educ*. 2018;23(2):118-30.
21. Chidgzey PJ, Davis S, Williams P, Reeve C. An outbreak of influenza A (H1N1) virus in a remote Aboriginal community post-pandemic: Implications for pandemic planning and health service policy. *Aust N Z J Public Health*. 2015;39(1):15-20.
22. Coffee N, Turner D, Clark RA, et al. Measuring national accessibility to cardiac services using geographic information systems. *Appl Geogr*. 2012;34:445-455.
23. Christiaanse S. Rural facility decline: A longitudinal accessibility analysis questioning the focus of Dutch depopulation-policy. *Appl Geogr*. 2020;121:102251.
24. Chandak A, Nayar P, Lin G. Rural-urban disparities in access to breast cancer screening: A spatial clustering analysis. *J Rural Health*. 2019;35(2):229-35.
25. National Rural Health Alliance. *How Many Doctors are there in Rural Australia?* Canberra (AUST): NRHA; 2013.
26. Australian Institute of Health and Welfare. *Mental Health Services in Australia*. Canberra (AUST): AIHW; 2021.
27. Australian Institute of Health and Welfare. *Australia's Health 2020: Health Workforce*. Canberra (AUST): AIHW; 2020.
28. McGrail MR, Humphreys JS. Spatial access disparities to primary health care in rural and remote Australia. *Geospat Health*. 2015;10(2):358.
29. Australian Department of Health. *Coronavirus (COVID-19) Case Numbers and Statistics* [Internet]. Canberra (AUST): Government of Australia; 2020 [cited: 2021 Feb 2]. Available from: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus-covid-19-current-situation-and-case-numbers
30. Queensland Government. *Roadmap to Easing Queensland's Restrictions*. Brisbane (AUST): State Government of Queensland; 2020.
31. Western Australia Department of the Premier and Cabinet. *COVID-19 Coronavirus: WA Roadmap* [Internet]. Perth (AUST): State Government of Western Australia; 2020 [cited: 2021 Feb 2]. Available from: https://www.wa.gov.au/organisation/department-of-the-premier-and-cabinet/covid-19-coronavirus-wa-roadmap
32. Macali A. *Vic Cases: Daily Confirmed Cases* [Internet]. Melbourne (AUST): Covid Live Australia; 2020 [cited: 2021 Feb 2]. Available from: https://covidlive.com.au/report/daily-cases/vic
33. Victoria Department of Health and Human Services. *Victoria's Restriction Levels* [Internet]. Melbourne (AUST): State Government of Victoria; 2020 [cited: 2021 Feb 2]. Available from: https://www.dhhs.vic.gov.au/victorias-restriction-levels-covid-19
34. Victoria Department of Health and Human Services. *Statement from the Premier - Based on the Advice of the Chief Health Officer, Stage 3 "Stay at Home" Restrictions will be Reinstated Across Metropolitan Melbourne and Mitchell Shire from 11:59pm on Wednesday 8 July* [Internet]. Melbourne (AUST): State Government of Victoria; 2020 [cited: 2021 Feb 2]. Available from: https://www.dhhs.vic.gov.au/updates/coronavirus-covid-19/statement-premier
35. Andrews D Hon. *Press Release - Premier of Victoria Statement on Changes to Melbourne's Restrictions* [Internet]. Melbourne (AUST): State Government of Victoria; 2020 [cited: 2021 Feb 2]. Available from: https://www.premier.vic.gov.au/statement-changes-melbournes-restrictions
36. Australian Bureau of Statistics. *1270.0.55.005 - Australian Statistical Geography Standard (ASGS): Volume 5 - Remoteness Structure, July 2016*. [Internet]. Canberra (AUST) ABS; 2018 [cited 2019 Feb 9]. Available from: http://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.005
37. Australian Bureau of Statistics. *1270.0.55.001 - Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas* [Internet]. Canberra (AUST) ABS; 2016 [cited: 2021 Feb 2]. Available from: https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1270.0.55.001~July%202016~Main%20Features~Overview~1
38. Australian Bureau of Statistics. *2074.0 - Census of Population and Housing: Mesh Block Counts, Australia, 2016* [Internet]. Canberra (AUST) ABS; 2017 [cited: 2021 Feb 2]. Available from: https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/2074.0Main+Features12016?OpenDocument
39. Coronavirus Victoria.. *Where to Get Tested* [Internet]. Melbourne (AUST): Victorian Department of Health and Human Services; 2020 [cited: 2021 Feb 2]. Available from: https://www.dhhs.vic.gov.au/where-get-tested-covid-19
40. *R*: software environment for statistical computing and graphics. Vienna (AUT): R Foundation for Statistical Computing; 2017.
41. *SPSS*: statistical software for Windows, Version 25.0. Armonk (NY): IBM; 2017.
42. *ArcMap*: software for mapping, editing, and analysis in a 2D environment. Version 10.7.1. Redlands (CA): Esri; 2019.
43. Pebesma E. Simple features for R: Standardized support for spatial vector data. *R J*. 2018;10(1):439-46.
44. Open Source Routing Machine. Route Planning Software [Internet]. Karlsruhe (GER): OSRM; 2020 [cited: 2020 Jul 24]. Available from: http://project-osrm.org/
45. Geofabrik. *OpenStreet Map Data*. Karlsruhe (GER): Geofabrik; 2020 [cited: 2020 Jul 24]. Available from: https://download.geofabrik.de/australia-oceania/australia.html
46. Barrington-Leigh C, Millard-Ball A. The world's user-generated road map is more than 80% complete. *PLoS One*. 2017;12(8):e0180698.
47. Australian Bureau of Statistics. *2033.0.55.001 - Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia*. Canberra (AUST): ABS; 2016.
48. Wollersheim D. *Code for the dataset titled: COVID-19 point-of-care-test sites in Victoria (24th July 2020): Average travel time and population catchment for each site*. [cited 2021 August 23]. Available from: https://github.com/dewoller/covid_testing_access
49. Lakhani A, Wollersheim D. *COVID-19 point-of-care-test sites in Victoria (24th July 2020): Average travel time and population catchment for each site*. [cited 2021 Oct 4] Available from: https://doi.org/10.26181/611085ef3f188
50. Mu L, Chen Y, Zhen C. SNAP office accessibility and its association with rurality. *Appl Geogr*. 2020;120:10.1016/j.apgeog.2020.102209.
51. Lakhani A, Parekh S, Gudes O, Grimbeek P, Harre P, Stocker J, Kendall E. Disability support services in Queensland, Australia: Identifying service gaps through spatial analysis. *Applied Geography*. 2019 Sep 1;110:102045.
52. Barbieri S, Jorm L. Travel times to hospitals in Australia. *Sci Data*. 2019;6(1):248.
53. Zhang Q, Northridge ME, Jin Z, Metcalf SS. Modeling accessibility of screening and treatment facilities for older adults using transportation networks. *Appl Geogr*. 2018;93:64-75.
54. Syed ST, Gerber BS, Sharp LK. Traveling towards disease: Transportation barriers to health care access. *J Community Health*. 2013;38(5):976-93.
55. Longacre CF. *Travel and Treatment among Breast Cancer Patients: A Population-Based Analysis* [Ph.D.]. Ann Arbor (MI): University of Minnesota; 2020.
56. Australian Department of Infrastructure, Regional Development and Cities. *Inquiry into the Indicators Of, and Impact Of, Regional Inequality in Australia*. Canberra (AUST): Government of Australia; 2018.
57. Australian Bureau of Statistics. *3218.0 – Regional Population Growth, Australia*. Canberra (AUST): ABS; 2020.
58. Shi Q, Dorling D, Cao G, Liu T. Changes in population movement make COVID-19 spread differently from SARS. *Soc Sci Med*. 2020;255:113036.
59. Giles ML, Hickman J, Lingam V, Buttery J. Results from a mobile outreach influenza vaccination program for vulnerable and high-risk populations in a high-income setting: Lessons learned. *Aust N Z J Public Health*. 2018;42(5):447-50.
60. Clarke KL, Burns E. Can co-location address fragmented rural mental health care delivery?-Regional evidence from Victoria, Australia. *Australas J Reg Stud*. 2017;23(2):174-94.
61. Wakerman J, Humphreys JS, Wells R, Kuipers P, Entwistle P, Jones J. Primary health care delivery models in rural and remote Australia – a systematic review. *BMC Health Serv Res*. 2008;8(1):276.
62. Harney BL, Brereton R, Whitton B, Pietrzak D, Paige E, Roberts SK, et al. Hepatitis C treatment in a co-located mental health and alcohol and drug service using a nurse-led model of care. *J Viral Hepat*. 2021;28(5):771-8.
63. Royal Australian College of General Practitioners. *General Practice: Health of the Nation 2018*. Melbourne (AUST): RACGP; 2018.
64. Australian Department of Health. *Medical Rural Bonded Scholarship (MRBS) Scheme* [Internet]. Canberra (AUST): Government of Australia; 2020 [cited: 2021 Feb 25]. Available from: https://www1.health.gov.au/internet/main/publishing.nsf/Content/mrb-scholarship-mrbs-scheme
65. Viscomi M, Larkins S, Gupta TS. Recruitment and retention of general practitioners in rural Canada and Australia: A review of the literature. *Can J Rural Med*. 2013;18(1):13-23.
66. Humphreys JS, Wakerman J, Pashen D, Buykx P. *Retention Strategies and Incentives for Health Workers in Rural and Remote Areas: What Works?* Canberra (AUST): Australian Primary Health Care Research Institute; 2009.