Identifying Gaps in Health Service Provision: GIS Approaches

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INTRODUCTION

This paper is based on work undertaken by the National Key Centre for Social Applications of GIS (GISCA) for the Department of Health and Aged Care and contained in the report “A Study of Health Services in Non-Metropolitan Australia — Final Reports”.¹

Australia has long been one of the world’s most urbanised nations with 86 per cent of Australia’s population living in urban centres of population size greater 1000 persons. In recent years there has been increasing attention directed at differences in levels of social well being and in service provision between the “city and the bush”. This has especially captured the attention of policy makers and politicians because the rural lobby has become increasingly co-ordinated and articulate and the fact that in recent state and federal elections there has been a swing away from the three mainstream political parties in many non-metropolitan electorates. Health is an important dimension in this debate and the Social Health Atlas of Australia² has shown clear gradients of declining health status and access to services with increasing remoteness

There are government commitments towards improving health services in non-metropolitan Australia but if these are to be effective it is crucial that the limited resources available be directed toward the communities who most need them and they are not diluted by spreading them across the entire non-metropolitan sector when in fact there are wide areas in this region which are currently adequately provided for while there are areas with poor levels of provision.

This paper discusses a range of geographical information system (GIS) methodologies for identifying significant gaps in health service provision in non-metropolitan Australia.

The first centres on points of provision of health services and buffers out from them to establish the populations who are within particular road distances of services.

The second approaches the problem from the point of view of non-metropolitan residents themselves and establishing their lack of accessibility to health services.

The third addresses the issue of how GIS can be utilised to establish the service areas of health servers in non-metropolitan Australia as a basis for better use of population:health service ratios

An underlying principle of this paper is that the delivery of health services in non-metropolitan Australia is best approached using a community-based strategy. In
establishing gaps in current provision it is important to take into account this community dimension. Provision of health services should be to communities and the dissemination of planning information to health professionals should be on the basis of the communities they serve rather than standard geographical units if they are to be the most effective and efficient in their work. It is suggested here that GIS offers a methodology, which can be helpful in developing a community-based health care system.

ESTABLISHING DATA SETS

In order to establish where gaps exist in health service provision in non-metropolitan Australia using GIS, it is necessary to assemble the main data sets that are geographically referenced. A GIS database was constructed that contained the following information:

- selected service information;
- road network;
- Census collection district boundaries;
- postcode boundaries;
- statistical local area (SLA) boundaries;
- ABS demographic data; and
- population projection data by SLA.

The services that were analysed included aged care facilities, Aboriginal medical services, general practitioners, home and community care, hospitals, Medicare services, multi-purpose health centres, pharmacies and dispensing agencies; and remote area clinics. As an illustration of the service data collected, the distribution of primary health care services is presented in Figure 1. For the purposes of this article, primary health care includes GPs, hospitals, remote nurses, pharmacies, home and community care, aged care, Aboriginal medical services (AMS), and multi-purpose service centres (MPS). The predominant pattern is of concentration along the east coast, southeast and southwest of the country.

In the paper no account is taken of the size or quality of the services provided at points. It should be possible in the future to take these factors into consideration since they are important elements in establishing the adequacy of provision of services. For the present purpose however we simply establish the locations at which each service is present.

Another important data set required for this study relates to the population of non-metropolitan Australia. This was derived from the 1996 Australian Census of population and housing. However it was desired to have a more flexible system than that allowed by utilising population data relating to SLAs. Ideally one required spatially referenced information which gave the precise location of each individual in non-metropolitan Australia as was available for health services. This would allow us to precisely establish the degree of accessibility of each individual living in non-metropolitan Australia to each type of health service. Unfortunately Australia does not as yet geocode census data and the smallest unit for which census population data are made available are census collection districts (CCDs).
In more sparsely populated areas however they cover substantial areas and there is significant mismatch between CCD boundaries and those of the areas served by health and service areas. It has been well recognised that both SLAs and CCDs in Australia do not coincide with areas of community interest over much of non-metropolitan Australia.

While there was no alternative to utilising CCD data to establish the number of people living in non-metropolitan Australia served by particular health services another source of information was accessed to establish the locations of where people lived in non-metropolitan areas. This was the data set of 11 338 places maintained by AUSLIG (Australian Land Information Group).

While we do not know the actual number of people living in the places recognised by AUSLIG they do indicate the precise location of most Australians living outside the major cities. The ABS provide census data for populated localities down to those with 200 residents but no data are available on the population size of localities with less than 200 residents in 1996.

Accessibility was measured by minimum road distance travelled by people to access health services. Distance was calculated using data from the AUSLIG 1:250 000 topographic map services using ESRI’s Net Engine and network analysis software package. These minimum distance calculations represented “accessibility” in the sense of ability to access services rather than the actual use of services. It assumes also that people will access the service nearest to them.
ESTABLISHING ADEQUACY OF HEALTH SERVICE PROVISION FROM POINTS OF SERVICE PROVISION

The first GIS approach adopted established the service area of each point of provision of health services by buffering out a set road travel distance. Analysis was undertaken using the GP database, but the methodology could be applied for any health service or combination of health services.

In the case of GPs it was assumed that the service area should be based on 80 km road travel what was considered to represent around 1 hour’s travel. All populated localities within this buffered zone would have access to a GP within 80 km and all those outside of those zones would not. The distribution of these zones is shown in Figure 2 and not surprisingly this indicates that there is a more or less continuous belt of coverage in the south eastern corner of the continent extending around 200 km inland from Southeast Queensland, incorporating the eastern half of New South Wales, all of Victoria and the incorporated area of South Australia. Other substantial continuous coverage is evident in all but south western Tasmania, most of the east coast of Queensland, and the south western agricultural corner of Western Australia.

Figure 2  Access by road to a GP within 80 km

The question now to be addressed is how can we go about estimating the population numbers and their characteristics within and outside of the zones of 80 km around each doctor location. In the present study these were estimated by proportioning the population of the CCD on the basis of the percentage of the area of the CCD that falls
within the zone or outside the zone. This assumes the population is evenly distributed over the CCD and provided a simple estimation of the number of people that lived within 80 km of a doctor and also a considerable amount of information about their characteristics.

The locations of all ABS urban centres and localities (ie all centres with 200 residents or more) which fell outside of the accessibility zones were mapped and they are shown in Figure 3.

**Figure 3** Locations of populated localities outside of the accessibility zone

![Map of Australia showing locations of populated localities outside of the accessibility zone](image)

The results of the analysis are presented in Table 1 and indicate that although 50 per cent of the total land area of Australia is more than 80 km from a doctor only 0.8 per cent of the national population live in this area (149 040 persons). This includes 86 settlements, which have 200 or more inhabitants. The fact that the Indigenous population are especially disadvantaged in access to health services is reflected in the fact that 37 per cent of the population outside the

<table>
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<th>Table 1</th>
<th>Demographic characteristics</th>
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<tr>
<td><strong>Outside 80km service area</strong></td>
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<tr>
<td>86 towns (with &gt; 200 people)</td>
<td></td>
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<tr>
<td>149 040 people</td>
<td></td>
</tr>
<tr>
<td>55 687 are of Indigenous origin</td>
<td></td>
</tr>
<tr>
<td>13 500 people are over 65 years of age</td>
<td></td>
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<tr>
<td><strong>Inside 80km service area</strong></td>
<td></td>
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<tr>
<td>17.7 million people</td>
<td></td>
</tr>
<tr>
<td>99.2% of Australia’s population</td>
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accessibility zones are Aboriginal but only 1.6 per cent of those inside the zones are. However it is recognised that health services for the Indigenous population are also provided by other services such as Aboriginal medical centres. The population living outside the accessibility zones is younger than that inside it but there are still some 13 500 people aged 65 years and over living more than 80 km from a doctor.

The system allows buffering to be carried out at any distance from the location of the health services. For example Figure 4 shows the pattern of accessibility zones when the road distance threshold is set at 40 km.

**Figure 4  Accessibility zones with road distance threshold set at 40 km**

This indicates that there is some breaking up of the continuous zone of accessibility in the southeast and southwest. Figure 4 overlays the 40 km and 80 km polygons. Nevertheless Table 2 indicates that the numbers outside the accessibility zones are increased from 149 040 to 314 200.

**Table 2  Summary of accessibility to GPs**

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<th>20 km</th>
<th>40 km</th>
<th>80 km</th>
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<tr>
<td>Total population outside</td>
<td>772 794</td>
<td>314 200</td>
<td>149 040</td>
</tr>
<tr>
<td>Indigenous population outside</td>
<td>72 910</td>
<td>62 950</td>
<td>55 867</td>
</tr>
<tr>
<td>% Indigenous population of total population outside</td>
<td>9.4</td>
<td>20.1</td>
<td>37.5</td>
</tr>
<tr>
<td>% Total population outside</td>
<td>4.3</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>% Total population inside</td>
<td>95.7</td>
<td>98.2</td>
<td>99.2</td>
</tr>
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However the strong spatial concentration of the national population is reflected in the fact that only 4.3 per cent of the total population live more than 20 km from a doctor (772,794 persons). It will be noticed in Table 2 that the proportion of the population living outside of the accessibility zones who are of Indigenous origin declines from 37.5 to 9.4 per cent as the threshold is decreased from 80 to 20 km. Nevertheless the proportion who are Aboriginal is more than twice that of the non-Indigenous population among the population more than 20 km from a doctor.

The analysis carried out above for doctors can be conducted for a particular health service or a combination of health services.

**ESTABLISHING ADEQUACY OF HEALTH SERVICE PROVISION FROM THE LOCATION OF CLIENTS**

An alternative GIS-based approach to establishing gaps in health service provision is to begin with the locations of all Australians living in non-metropolitan populations and measure their access to services. Clearly there will be situations where people will bypass the nearest service to use a more distant service but in the analysis here it is assumed that people will use the service that is closest to them by road from their home. This analysis began with the 11,338 AUSLIG localities in non-metropolitan Australia and calculated the road distance from each of them to the nearest health services in the categories discussed above. Each of these places was then categorised according to its degree of access to each type of health service. Figure 5 shows the pattern that results from the analysis for doctors. The darkness of the symbols for each locality indicates increasing road distance from doctors. Most of the rangelands area of Australia has localities in the least accessible category although there are islands of slightly better accessibility around large centres like Darwin, Alice Springs, Mount Isa, Broome etc.

GIS can also be used to present the pattern as a continuous surface as is shown in Figure 6 which classifies the entire area of non-metropolitan Australia according to accessibility to doctors. A clear pattern emerges in the map. As is the case with the previous methodology population numbers can be assigned to the various categories using the same methodology to establish the numbers of people in the various accessibility categories.

In addition this approach also allows us to “zoom in” on the pattern in specific areas. For example Figure 7 depicts the situation in the state of New South Wales.
Figure 5  Distance to a GP by road

Figure 6  Accessibility surface to GPs
DEFINING CATCHMENT AREAS OF HEALTH SERVICES

Most past analyses of the adequacy of health services in non-metropolitan areas have adopted an approach of calculating population to service ratios for standard geographical regions. A typical example is provided in Figure 8, which depicts the number of people per GP in non-metropolitan Australia. As was indicated earlier this approach has a number of problems especially the fact that the spatial units do not coincide with the actual catchment areas of health services.

Hence situations emerge such as that shown in Figure 9, which is part of Western Australia “zoomed in” from the previous figure.

Kalgoorlie SLA with 28 doctors and 29 000 people shows up as being well served while adjoining Coolgardie with 2 doctors and 6000 people is under served, and yet it is clear that many Coolgardie residents utilise health services in Kalgoorlie. For any such analysis to establish under- and/or over-provision of health services it is necessary to establish the catchment service areas of the services and then establish the adequacy of provision within those areas. GIS can be utilised to undertake this.

The first step in defining catchment areas using GIS is to assign each of the 11 338 localities to its closest service (in this case GP) by road. The “natural catchment” area of each service can then be drawn in half way between each outermost locality and the nearest locality to it going to another point of provision. The “natural catchment” boundaries for GPs derived using this method for non-metropolitan Australia is depicted in Figure 10.
Figure 8  Population per GP for SLAs

Figure 9  Population per GP in WA
These catchment areas can then be assigned to categories, which show catchments with population to GP ratio around the average and those with ratios above and below the average. The map shows a clear pattern of under-provision in substantial areas in remote Australia. However there are also isolated areas of under-provision in the more closely settled parts of non-metropolitan Australia. Each of these areas needs to be closely studied to establish the degree and nature of the shortage. The GIS methodology thus provides a way of identifying areas for attention and targeting for resource allocation.

The lack of coincidence between these “natural” catchment boundaries and those of standard geographical areas is evident in Figure 11, which analyses the catchment boundaries with those of SLAs in non-metropolitan areas.

The fact that standardised spatial units are generally not socially or economically meaningful units for planning of health service provision and allocation of resources in much of non-metropolitan Australia is evident.
FUTURE WORK AND CONCLUSION

This paper has indicated the potential of GIS to assist in identifying gaps in health service provision in non-metropolitan Australia. It has presented three ways in which GIS can be employed to this end and in doing so has identified areas of low accessibility to health services and under-provision of such services in non-metropolitan Australia. While this is useful to health planning in Australia several refinements are needed to sharpen the systems as tools for efficient and equitable service provision. It is suggested here that further work is needed in the following areas:

♦ better definition of catchment areas;
♦ better estimation of population numbers and characteristics;
♦ refined measures of accessibility; and
♦ assessment in catchment areas of not only the location of services but their quality and scale.

Firstly regarding the definition of catchment areas, it is argued that this is an important priority because it is fundamental to the adoption of a more community-based approach to health service planning. The development of more meaningful regions is not only essential for assessing the adequacy of health service provision but also for many other areas of health planning and provision. The GIS-based approach adopted here is just one method. A range of other GIS methodologies can be utilised using similar data to
that used here. However there is a need to examine other possibilities of defining community of interest areas in non-metropolitan Australia, which are based on communities’ interactions and identification with particular urban places. One approach which is currently being experimented on in a study of metropolitan Adelaide is to obtain data on actual use of health services (e.g. doctors) and geocoding the home locations of users of health services to define the borders of the service area. Of course this raises a number of important confidentiality issues some of which require some analysis of records maintained by the health services themselves as centrally maintained Medicare records. This approach however would have the utility of also being able to be used to supply information to health providers and communities of the nature of the populations in those communities of interest areas and exactly how incidence of disease, use of services etc compares to other areas. It also would provide a powerful tool in the maintaining and evaluation of interventions.

Another approach is to define more generic community of interest areas for non-metropolitan towns and cities so that a hierarchy of areas which are actually served by centres and with which people within them identify with those centres is developed. It is argued here that the definition of such areas is an important pre-requisite of community-based approaches to planning and resource allocation in non-metropolitan Australia. The definition of such areas is not simple. One approach adopted in the United States is to utilise journey to work census data to establish the boundaries of the labour market of towns and cities. Their labour markets are closely related to community service areas. This is currently not possible because although journey to work questions are included in the census the data collected are only analysed for in and around major urban areas.

The second issue relates to the estimation of population numbers and characteristics within the catchment areas of health services. The approach adopted here was to assign a proportion of the CCD to a catchment area on the basis of the percentage of the CCD that falls within the catchment area. It would clearly be more satisfactory if the populations in catchment areas could be estimated more precisely. The obvious solution is for census data to be geocoded so that the locations of people and households can be assigned to their appropriate catchment areas. While the ABS are investigating this option, it is unlikely to occur in the near future. Accordingly it is necessary to explore some other options of estimating populations of catchment areas. The problem is most acute in the sparsest settled parts of the non-metropolitan area where CCDs are largest. This also is the area where health service problems are often substantial so a solution is especially needed in those areas. One solution is for the ABS to consider the release of population numbers (not the detailed tables currently provided for CCDs) for sub areas within CCDs. A related approach is adopted in Canada and New Zealand where data are available for sub collection district level with statistical authorities being able to aggregate them to conform with the boundaries of areas desired by users such as catchment areas, river basins etc.

Failing the above which require a change in ABS policy it is necessary to develop techniques of estimating sub CCD population distribution. One important step, which can be achieved using GIS, is to mask out of consideration all non-inhabited or near non-inhabited parts of the CCD. There are a number of sources, which could be utilised to identify these uninhabited areas. These include the National Wilderness Inventory
and the Natural Forest Inventory and possibly air photos can be utilised in this process as well. The meshing out of uninhabited areas would be an important step of other approaches to distribute the CCD population within its boundaries.

In the CCDs, which contain a populated centre, there is a need to estimate the population at these places (ABS only provides population figures of towns greater than 200 persons). Once estimated that centre’s population can be extracted from the CCD total and the remainder distributed through the rest of the CCD area. This could be achieved using a number of techniques:

♦ random distribution;
♦ use of air photos which show settlement;
♦ telephone connections, and
♦ property cadastre information

Once the distribution of population within CCDs is determined it is possible to use a range of extrapolation techniques to establish some basic characteristics of the population in terms of age, sex, ethnicity etc. The extrapolation would be from the CCD census information. It is evident for better planning of service provision that the populations of catchment areas be able to be broken down by age, gender, ethnicity, socioeconomic profile etc. This is because the level and nature of need for particular health services varies considerably according to the characteristics of the population being served. This would enable greater analysis to be made of equity considerations.

The third area which needs further research relates to the measures of accessibility adopted here. Nearest road distance to a service is an improvement on using straight line distances. Nevertheless there are a number of problems, which stem from:

♦ no differentiation of the roads according to surface, quality, availability of transport, seasonal variation in conditions etc; and

♦ no differentiation of people’s ability to utilise the road system for travel.

An obvious improvement would lie in ways to estimate travel times.

A fourth area for improvement in the systems presented here relates to the data on the health services themselves. Only points of provision have been included here but a refined model would go beyond this. It would include some measure of the quality of the service and the scale of services provided. It may also be possible to include a measure of not only the nearest services but the nearest two or three services to take into account the desire of many users of health care systems to have choice in the services they use. Some account needs to be taken of part time services, accessibility to the flying doctors etc.

The present paper is a beginning to the development of GIS-based systems to identify communities in non-metropolitan Australia, which are under provided with health services. The systems developed represent a considerable advance on previous methodologies but there is an urgent need to develop them further and refine their inputs if the particular health needs of Australians living outside major cities are to be addressed in a more targeted and focused way.
REFERENCES

1. A study of the provision of health services in non-metropolitan Australia — final reports, for the Department of Health and Aged Care, the National Centre for the Social Applications of Geographical Information Systems (GISCA), May 2000.


AUTHORS

Errol Bamford is the Research Manager at the National Key Centre for Social Applications of GIS. He is one of Australia’s most respected GIS practitioners, and has over 20 years’ experience in GIS technologies, particularly applied to social planning issues. He has detailed knowledge of Australian socio-demographic databases and GIS hardware/software packages; extensive experience in application of GIS technologies to health service delivery; and has been involved in the design and development of many health-related, web-enabled spatial information systems. He is currently the team leader of over 12 health and GIS projects.