The role of GIS in supporting evidence-based rural health service planning and evaluation: A New Zealand case study

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Equity of access to health services is a concern of rural communities worldwide and a fundamental principle of the New Zealand Health Strategy. Planning for rural health services often takes place without adequate information for robust decision-making.

A Geographic Information Systems (GIS) project was developed to link pre-defined rural health service areas to a database for two key purposes:

1. To be able to define and select a service area containing census population data and view current health services available to that population; and
2. To be able to view health service coverage for a set of one or more criteria and query the population that it serves.

The project involved a survey of rural health practices and the development of a secondary tool to query demographic data in conjunction with health services planning and monitoring criteria.

Introduction

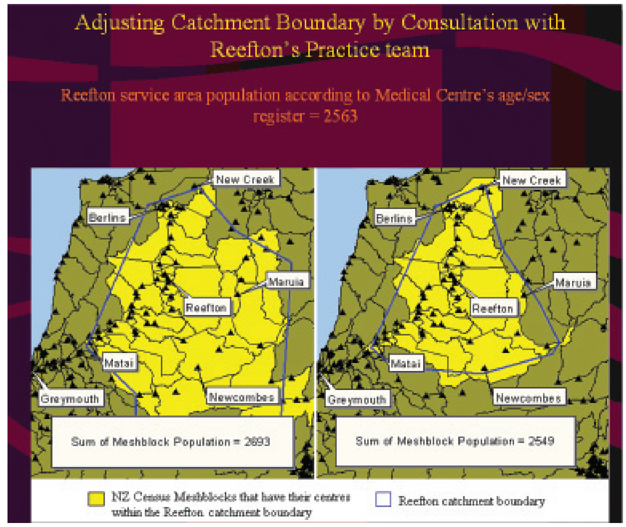
The application of Geographic Information Systems (GIS) technology is growing rapidly, although unevenly, in health care. In some cases it requires a large institutional commitment to design and implement a GIS but, with increasingly affordable solutions, choices for smaller organisations and for smaller client groups are improving. While much of the historical focus in health GIS has been on epidemiological issues, i.e. variations in health outcomes and possible reasons for observed patterns, interest is increasing in using GIS to target health care planning concerns, i.e. the organisation and configuration of health services and effects on accessibility and utilisation. Recent examples include the Dartmouth Atlas of Health Care,[1] the UK atlas of health service performance[2] and the Spanish Atlas of Small Area Mortality.[3] In addition, there is a growing interest in integrating GIS into existing health data collection and analysis strategies as a way of gaining additional value from those activities and using GIS to improve the communication of that information to a broad range of audiences within and external to health service providers.

Access to general practice (GP) services has been an important issue for some GIS studies, especially when combined with theories about distance to care, social disadvantage and the health outcomes of measured or modelled disadvantage.[4–7] Hyndman and Holman (2001) used GIS in Perth, Australia, to investigate distances to GP services and mapped these against socioeconomic levels and GP hours, consultation numbers and staff nurses.[7] They found that quality of service indicators in this study were 'reasonably equitable' and attributed this to Australia's bulk billing approach to publicly funded primary care. However, they also identified other international studies that suggested measurable gradients in the quality of and access to primary care physicians, including McIntyre et al. (1993),[5] Anderson and Rosenberg (1990)[6] and Knox (1978).[7] Knox in particular was concerned with the effect of distance from home to providers and the impact this had on care seeking behaviour.

Health service inventories are seen as a basic step in improving health services management and planning, including policy formulation and service modelling. They are also a necessary phase in the development and extension of practical GIS systems for health care planning and management. The process of inventory development requires allocating the resources to identify and follow-up information on health services within geographical areas of interest. Our experience in the New Zealand context is that information on the nature and availability of health services and their methods of provision for any given rural community are best obtained from within that rural community rather than from any centralised agency. This information is known by various local service providers and other key local information brokers. This data is often global in nature, transcending traditional service boundaries, and is often highly localised geographically.

The Southland and Otago provinces are geographically adjacent and the District Health Boards (DHBs) administering their respective health services have a close working relationship. However an accurate overall picture of their health services has, until now, been viewed as difficult to obtain and therefore little investment had gone into this process. The development of a GIS investigation offered a possible innovative solution.

Figure 1. Adjusting catchment boundary by consultation with Reefton's practice team



Methods and results

Otago and Southland are two provinces in the South Island of New Zealand/Aotearoa. Te Waipounamu Rural Health Unit at the University of Otago worked with the University's Department of Information Science to produce the GIS.[8] Later the Otago District Health Board (ODHB) assisted with the project and began to use the GIS technology to support and enhance their service planning methods, data collection and information dissemination strategies.

The first step was the construction of a stock-take database as a means of recording health services within any given area at a given point in time. A method of combining Statistics New Zealand mesh-block census data[9] with local health provider on-call boundaries was used to define the limits of these areas. Each area's services was recorded, allowing geographic analysis of the entire rural health services provided by the Otago and Southland DHBs.

It was decided that the capabilities of a GIS would provide the best method to analyse, represent, and display this information. The ability of a GIS to identify spatial relationships between services and create the potential to recognise hitherto hidden gaps and anomalies in service coverage was seen as key.

Service areas

This GIS included information from all the rural practices in the South Island. Te Waipounamu Rural Health Unit at the Dunedin School of Medicine in collaboration with the Department of Information Science of the University of Otago had previously produced a GIS of service areas based on General Practitioners' Shared Roster Areas.[8] A shared roster area refers to the area served by a group of GPs who share an after-hours call roster. These areas were defined by the local health professionals and included input from the local GPs as well as practice nurses, practice administration and St John's Ambulance staff. The straight-line boundaries of these service areas were then re-aligned to coincide with existing Statistics New Zealand's mesh-blocks, which are the smallest spatial units at which data can be provided or identified. Using census data contained within mesh-blocks, the total populations contained within the service areas was checked against the age/sex registers of the practice. If the practice age/sex register was approximately equal to the census population, the service area boundary was taken as accurate. If there was a discrepancy between the two and the age/sex register proved to be accurate the service area boundaries were reviewed with the local providers and practice staff.

The map on the left of Figure 1 shows the service area boundary initially outlined by providers at Reefton. The map on the right shows the reviewed service area boundary, which corresponds more closely to the practice's age/sex register. This approach expresses the reality of shared roster areas by reflecting natural population flows. This is extremely important for health service planning and comparisons of access. Assumptions regarding access to services made using distance from service or estimated travel times may be misleading. Neither of these measures allows for other factors that may influence the reality of choice of location of services that rural populations may access, such as local geography and location of other services and facilities, e.g. shops, pharmacy and so on.

Evidence for the optimum placement of specific services within these shared roster areas was also obtained from the GIS. When a shared roster area includes three small towns of similar size and it becomes necessary to add one more GP because of workload, the use of GIS allows a more informed recommendation of the best site for the additional service. Figures 2–4 are GIS maps of the Western Southland Shared Roster Area showing road travel iso-lines at 10, 20, 30, 40 and 50 km distances from each town and the percentage of the population, which is within each iso-line when an extra GP is located in Riverton (Figure 2), Tuatapere (Figure 3) and Otautau. With this information it becomes clear that the best town for the extra GP to live in is Otautau because that situation will give the best after hours travel conditions for the GP for the largest proportion of the population of the roster area. In this way, the GIS can be used to support rational decision making processes that support the interests of both communities and providers, as well as helping to build a picture about the potential consequences of alternative decisions. The implications of service planning in terms of site can be determined and expressed more effectively.

Service characteristics

We surveyed rural practices in Otago and Southland to define regional workforce capacity and the range of services provided by individual general practices. These data were stored and spatially linked to the GIS project[10] to enable: selection of different service areas and their current available health services; views of health service coverage for a set of one or more criteria and identification of the population served; querying demographic data within service areas in conjunction with actual service availability and comparison with the ideal.

Layers of data were constructed from rural service area information and the workforce and service information. Rural service areas (defined by GP practices within that area) were added as described above. Regional workforce and service data were gathered by surveying local health practitioners, including the individual GPs within each practice, by use of postal questionnaires and phone follow up. These questionnaires were concise, with answers mainly limited to yes/no or a number (such as workers in a particular service or units of service provision such as beds in a hospital).

Questionnaire data were stored in a database that allowed ease of data entry and retrieval. Users can enter the database at any level and link to data at a higher or lower level, i.e. select a region and view its information but also drill down and view the practice and GP information and drill up as required (Figure 5). The database was also designed to enable data review by producing reports of pre-filled questionnaires for regular updates (yearly). These will be sent to all health professionals, practices and GPs in each area (Figure 6). These data could also be updated by local primary health organisations (PHOs) on line. The system could become more self sustaining and interactive, with PHOs ensuring their own information is accurately updated.

A GIS customised tool was created that when activated allowed a user to click on the catchment theme

Figure 2. Western Southland – Access times if extra GP is in Riverton

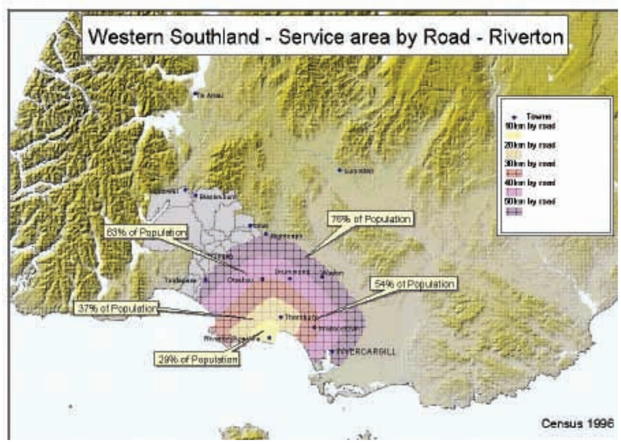


Figure 3. Western Southland – Access times if extra GP is in Tuatapere

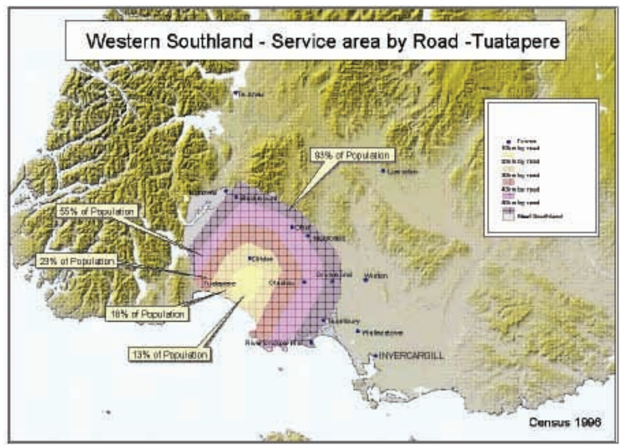
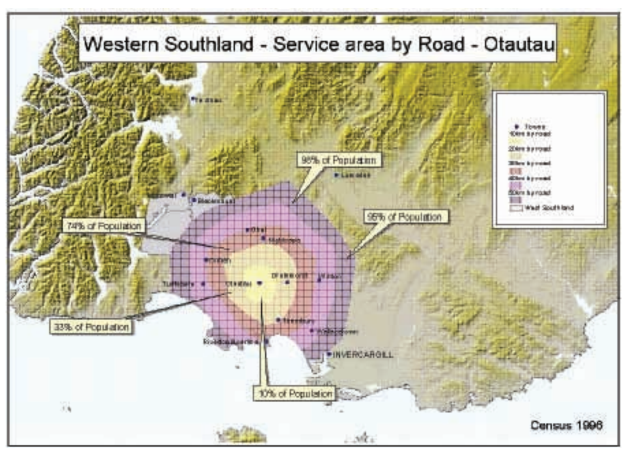


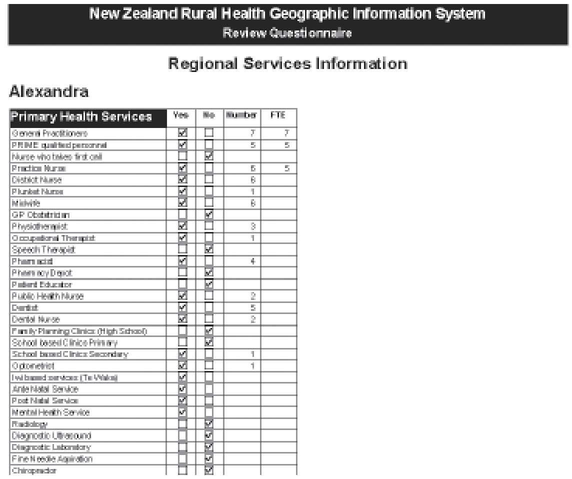
Figure 4. Western Southland – Access times if extra GP is in Otautau



(Figure 7) that located the current health services available to that area. A query builder within the GIS was developed for this dataset to enable viewing of health service coverage. This query builder allowed selection of one or more health services and shows where these services intersected (Figure 8). Catchment areas match-

Figure 5. Data captured at Rural Service Area (Region) level

Figure 6. Example of questionnaire for review



New Zealand Rural Health Geographic Information System
Review Questionnaire

Regional Services Information

Alexandra

Primary Health Services	Yes	No	Number	FTE
General Practitioners	☑	☐	7	7
PRIME qualified personnel	☑	☐	5	5
Nurse who takes first call	☐	☑		
Practice Nurse	☑	☐	6	5
District Nurse	☑	☐	6	
Plunket Nurse	☑	☐	1	
Midwife	☑	☐	6	
GP Obstetrician	☐	☑		
Physiotherapist	☑	☐	3	
Occupational Therapist	☑	☐	1	
Speech Therapist	☐	☑		
Pharmacist	☑	☐	4	
Pharmacy Depot	☐	☑		
Patient Educator	☐	☑		
Public Health Nurse	☑	☐	2	
Dentist	☑	☐	5	
Dental Nurse	☑	☐	2	
Family Planning Clinics (High School)	☐	☑		
School based Clinics Primary	☐	☑		
School based Clinics Secondary	☑	☐	1	
Optometrist	☑	☐	1	
Iwi based services (Te Waka)	☑	☐		
Ante Natal Service	☑	☐		
Post Natal Service	☑	☐		
Mental Health Service	☑	☐		
Radiology	☐	☑		
Diagnostic Ultrasound	☐	☑		
Diagnostic Laboratory	☐	☑		
Fine Needle Aspiration	☐	☑		
Chiropractor	☐	☑		

ing the criteria are then highlighted within the GIS (Figure 9). Additionally some health service data include frequency of use. Using a second query option, a chloropleth map (thematic map) can be produced showing the different classifications of visitation frequency (Figure 10).

Having selected these areas, further analysis can be carried out by selecting the mesh-blocks (Figure 11) in these areas (using a single-click customised tool) and obtaining the Statistics New Zealand 2001 census demographic data attached to these mesh-blocks (within the GIS tables). This allows the consumer population to be analysed. Redefining the GP catchment area boundaries to match to mesh-block boundaries will allow more accurate analysis of the demographics within these catchment areas. At present some mesh-blocks are shared between catchments, thus allowing some slight data inaccuracies when analysing the data.

A second query builder interface was developed to allow querying of data from the Statistics New Zealand 2001 census. These data related to each mesh-block and contained demographic (age and ethnicity), household and dwelling, labour force, and socio-economic (deprivation index) information. We also wished to include smoking data as this is a key health indicator. Unfortunately there was no question about smoking in the 2001 census so the data from the 1996 census question *'Are you a regular smoker?'* was incorporated into the query builder. If smoking data is queried, mesh-blocks from the 1996 dataset are selected, matching the criteria and records within the 2001 dataset whose mesh-block boundaries match or are contained within the 1996 mesh-block boundaries.

Census data are not available at an individual record level so each rural mesh-block contains aggregated data on approximately 100–150 people. There is also only a 65+ years aged group, with no finer age definition within

Figure 7. Customised tool example. Clicking on a catchment area will open the database at the related record.

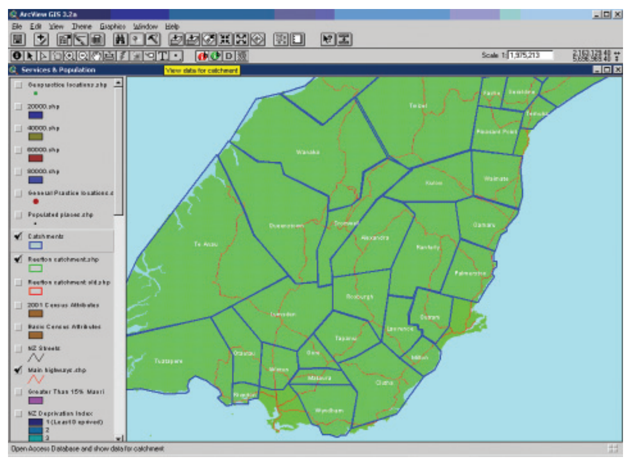


Figure 8. Health services query builder

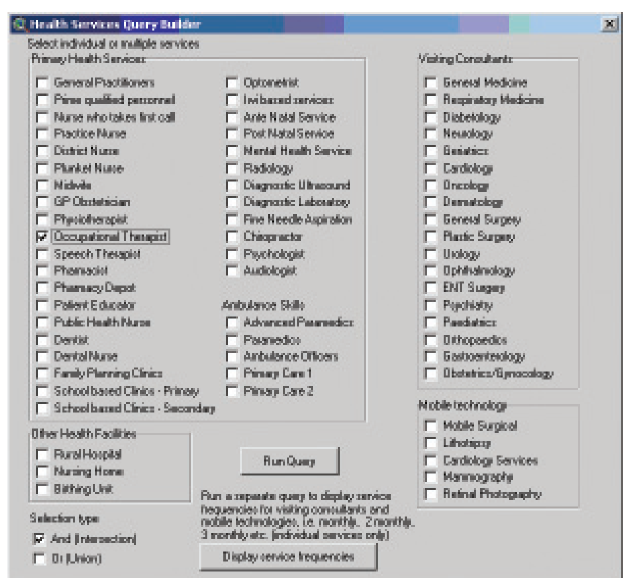


Figure 9. Results of query showing health services coverage for one service (occupational therapy)

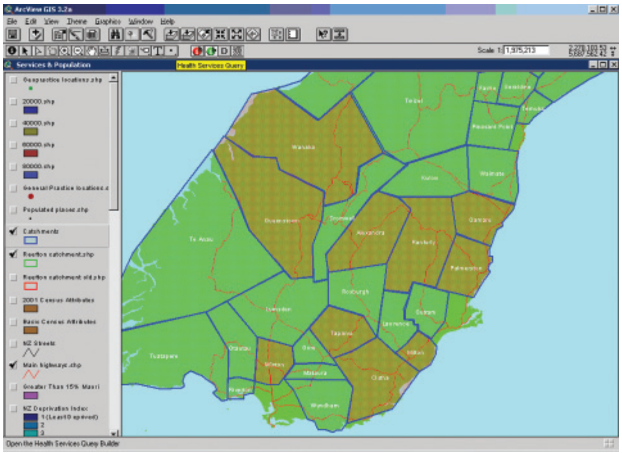
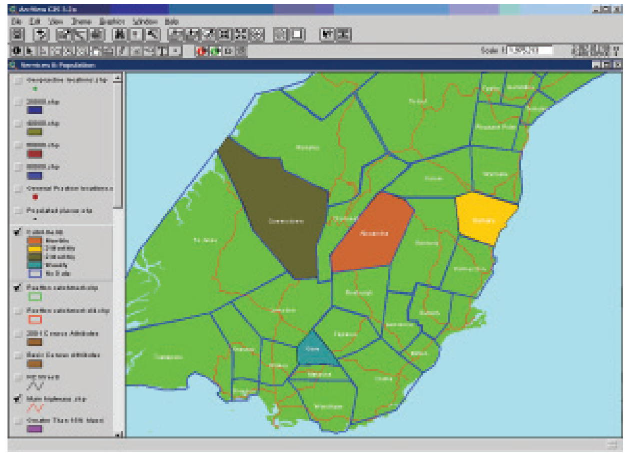


Figure 10. Chloropleth map showing visiting consultant frequency (neurology)



this group. These restrictions are due to privacy issues. Therefore it is not possible to query the dataset with a question such as: '*Show me all females aged 50–55 who identify as Maori*.' The data can only be queried in terms of percentage of the total mesh-block population (or number of occupied dwellings, total of labour force as the case may be). This means we are restricted to identifying concentrations of a certain group or combinations of groups such as: '*Show me all mesh-blocks where there are 15% of people who identify as Maori and 25% who are aged over 65*.' This is a quite different question to the one above and it may be that some areas meet these criteria even though there are a very small number of people aged over 65 and Maori. However to date users of this query builder have some knowledge of the demographic makeup of the Otago/Southland population and are careful to choose criteria to fit within the data and demographic constraints.

Using the tools

The results from this demographic query tool combined with actual service availability allow comparison with the ideal. Suppose, for example, we want to investigate paediatric service availability to the population aged under five years. We know in Otago/Southland that the under-five population is approximately 6% of the total population so we want to see if the regions with higher concentrations of this age group are best served. Running a query that highlights mesh-blocks where the population of under-fives is 15% or more of the total population gives a good indication of the spatial coverage of this age group (Figure 12). Of the service data available, the paediatric visiting consultant service is the most appropriate for this age group. Overlaying this service coverage we see there is adequate service coverage over the Otago/Southland region (Figure 13) but ideally this coverage could extend to the Lumsden, Gore and Wanaka

Figure 11. Highlighting mesh-blocks from the areas selected by the query builder

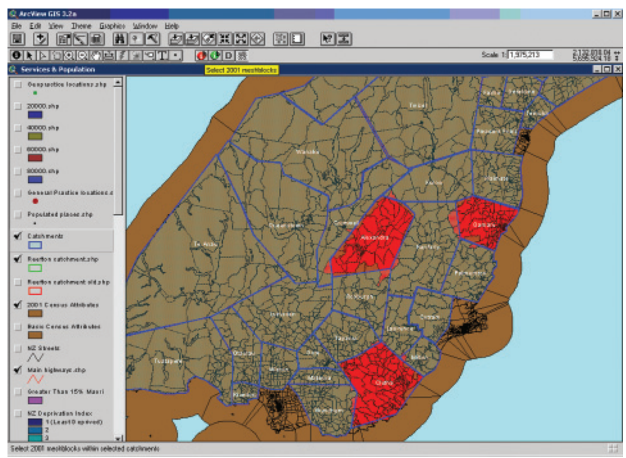
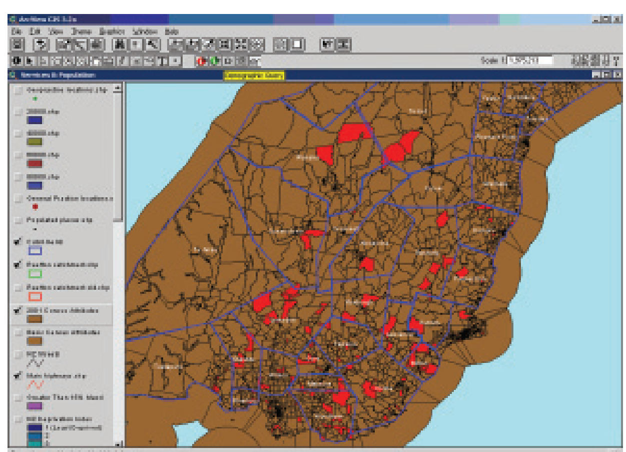


Figure 12. Results of query showing areas (red-coloured mesh-blocks) where the under-five population constitutes 15% or more of the total population



regions along with consideration of the Roxburgh and Twizel areas' accessibility to this service.

Discussion

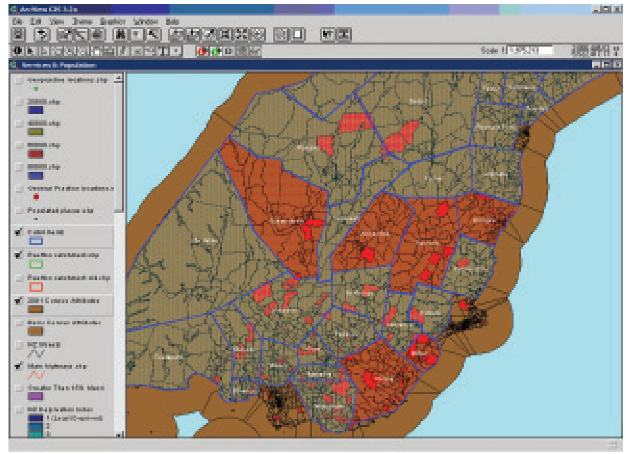
There is a growing recognition of the need for improved spatial analysis tools to help health service planning for rural communities.[11] The aim of this project was to use GIS technology to support rural health care planning across two provinces in New Zealand with strong rural sectors, complex geographies and finite health care provider networks. While a trial process in the initial stages, the intention also was to illustrate and provide evidence of the utility of GIS technology in supporting rural health service provision and planning. The project initiated processes that had never been undertaken before, including a comprehensive survey of primary health care providers in the two provinces, identification of the type and range of services provided by individual practices, as well as modelling the impact of additional service providers, optimal locations for selected providers and the coverage of specific services available to populations by area.

And benefit of the process was that it enabled more extensive use of 'what if' scenarios to support planning processes because GIS supports this type of analysis via a visual output, i.e. maps. Together, this ability to query the available data and to visualise the results of those inquiries represents a fundamental change to the way primary care planning has historically been conducted in sub-national health care planning processes.

This project combines data obtained both at local and central levels to reflect an accurate picture of reality. For example, a recent study[12] examining hospital access in New Zealand produced anomalous results because the authors relied on a hospitals list provided by the Ministry of Health. The list was inaccurate because it excluded several hospitals,[13] and did not reflect their level of function (unpublished data presented at NZ Rural Health Summit, July 2005, Wellington). The lack of easily accessible and accurate data can limit the effectiveness of any analytical tool.[11] Some of the data used in this project may also be inaccurate because it relies on a questionnaire of individuals and organisations. However, it is more likely to reflect the reality, especially at the local level, than other models, and is likely to increase in accuracy as the project continues. A system used for research and planning needs to put the necessary resource into accurate data gathering as well as into the analytical tool and methodology, especially if the system is to have ongoing use.

This project has proven extremely valuable at a number of levels. It allowed planners to capture data in a centralised format that had previously only been available on an ad hoc, case-by-case basis. It created an inventory of not only practices themselves but also the range and frequency of services provided by or at those

Figure 13. Overlaying the paediatric service coverage on the demographic query results



practices, including variables such as visiting specialists' schedules for rural practices.

Limitations to the project include the fact that it was a trial project with limited resources and funding support. The ability to provide access to the GIS for health care providers themselves has also been limited by infrastructural problems and there is no capacity as yet to make the GIS available via the Internet to general practitioners, practice nurses or PHOs. The development of open access web based GIS offers an opportunity for the future.[14] A limitation to ongoing usefulness of this system is that its value and accuracy reduce dramatically unless its databases are regularly updated. Future development of this project includes interest shown by other District Health Boards in conducting similar projects to capture the health infrastructure and geography of their own localities.

The most important outcome from the perspective of the project team has been that for a relatively small investment in time and money, and with dedicated staff, we have shown that it is possible to use GIS technology to build a coherent picture of health service provision and the gaps in current services at a population level for rural areas. The value of this has yet to be fully appreciated in broader health planning circles, which tend to use GIS to analyse factors such as intra-regional disparities and comparison rates. However, the growing sophistication of GIS technology and the decreasing investment cost of incorporating GIS as a planning and service management/development tool shows long term scope for building the value of this technology across the scope of health service provision from the macro or national scale down to comparatively small regional and rural areas. We anticipate the role of health GIS will grow as applications for supporting the health of rural communities and specific client populations (such as those with disabilities, chronic conditions and age-related frailty) become both obvious and important in health systems constrained by finance and continued population growth. The ability to direct patients and carers to locally available supports or to allocate resources to emerging needs can only be enhanced by this type of GIS application.

Conclusion

Multiple level health service and population data accessed via GIS with a sophisticated query builder offers an exciting approach to rural health service planning in the future. The possibility of providing this service on a web-based system allows the whole process of service planning to be more transparent. Rural communities and their PHOs will be able to see for themselves the reality of their situation compared to others and analyse the implications of proposed changes or developments in a more informed manner. The principle of combining locally available data with national data is important for informed health service debate. The methodology is not specific to the New Zealand situation, and therefore the value of a GIS constructed in this way should be apparent in other countries with similar issues of rural health service delivery. The potential of this GIS or others like it to facilitate the achieving of equity of health services for rural areas is exciting. The methodology has applicability in fields other than health, and could also be adapted for urban use.

Fiscal and political pressures lead to the restructuring of health services, usually with the goals of equity of access and economic efficiency. New Zealand's experiences of health service restructuring are unique in the sense that the country is small with a relatively low population density and a complex geography compared to other developed countries. This means that economies of scale are hard to realise without innovative approaches to technology and infrastructure planning. GIS technology is one way of adding value to existing information collection methods and innovating in health service planning and information dissemination, especially in rural areas with limited health infrastructure.

Competing interests

None declared.

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Patients' health literacy

'The impact of low literacy on healthcare costs is sobering. Last year a report …flagged up by the online press release source Business Wire, estimated that low health literacy cost the US economy between $106bn and $236bn each year. Although these are only ballpark figures, such colossal sums must provide food for thought in all countries in these cash strapped times. At the very least they should stimulate a drive to increase health literacy through efforts to inform, educate, and involve patients in their health care.'

Richards T. Border Crossing: Copy them in. BMJ 2008;337:a2324