

Planning for the future: Addressing the spatial accessibility of  
aged residential care facilities in New Zealand

BY

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## Abstract

Evidence in New Zealand suggests that spatial access to aged residential care facilities (ARCFs) has been declining. Poor spatial access to facilities has been shown internationally to lead to reduced frequency of visitation by family and friends, and in turn poorer mental health and wellbeing of people in care. However, the New Zealand population is ageing and older people are increasing as a proportion of the total population. Subsequently, total demand for ARCFs is set to increase dramatically and a substantial number of facilities will likely need to be built by 2026. The intent of this thesis is to explore how geographic information science (GIS) methods can be used to identify potential locations for these ARCFs in New Zealand so that travel time for friends and family is minimised.

Providers were surveyed on the relative importance of a series of spatial attributes when deciding where to place new facilities. Maps for each spatial attribute were generated from their preferences and overlaid using weighted linear combination and areas exceeding a suitability threshold were identified as potential locations. To choose optimal locations, maximal covering location-allocation models were used based on projected populations and demand for 2026. The spatial accessibility of these locations was then compared to the spatial accessibility of facilities in 2011. The results suggest that GIS methods have the potential to improve the spatial access to ARCFs to friends and family of people in care.





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## Abbreviations

2SFCA	Two-Step Floating Catchment Analysis
API	Application Programming Interface
ARCF	Aged Residential Care Facility
ARRC	Age Related Residential Care Contract
AU	Area Unit
BPSD	Behavioural and Psychological Symptoms of Dementia
CCPS	Client Claims Processing System
CMCLP	Capacitated Maximal Covering Location Problem
CSV	Comma Separated Variable
DHB	District Health Board
GIS	Geographic Information Science
GP	General Practitioner
GPS	Global Positioning System
HLAM	Hierarchical Location-Allocation Model
LCPA	Least Cost Path Analysis
LINZ	Land Information New Zealand
LSCP	Location Set Covering Problem
MB	Meshblock
MCLP	Maximal Covering Location Problem
MOH	Ministry of Health
NZDep2006	New Zealand Deprivation Index 2006
NZHIS	New Zealand Health Information Service
NZTM2000	New Zealand Transverse Mercator 2000
OECD	Organisation for Economic Cooperation and Development
SLAM	Single-Level Location-Allocation Model
WGS84	World Geodetic System 1984
WLC	Weighted Linear Combination





## 1. Introduction

Access to aged residential care facilities (ARCFs) in New Zealand is becoming increasingly inequitable. As decreasing profits compel providers to increase the size of their facilities to meet minimum operational efficiencies, smaller facilities without the capacity to expand and facilities in areas with insufficient demand to support expansion are likely to close (New Zealand Labour, Green Party of Aotearoa New Zealand, & Grey Power New Zealand, 2010).

This falling access is further exacerbated by falling proportional demand for aged residential care services. Historically ARCFs catered for older people with varying levels of dependency, from low dependency residential care to high dependency hospital care. However changes in policy and the proliferation of alternative forms of care have meant that current aged residential care is used almost solely by those with high dependency (Boyd et al., 2011). As such, demand has fallen over recent years and is expected to continue to fall, until all lower dependency needs are serviced by alternative forms of care, and only those with higher needs access ARCFs (Grant Thornton, 2010).

The combination of these two factors has meant many facilities in rural areas without adequate demand have been, or will likely be, forced to close (New Zealand Labour et al., 2010). For an increased proportion of the New Zealand population therefore, moving into an ARCF will mean moving further from their communities, their families and their friends (New Zealand Labour et al., 2010; Rural Women New Zealand, 2010; Taylor, 2011).

### 1.1. Research focus

It is well established in the literature that the move into aged residential care can be a traumatic experience for many older people and a painful experience for their families (Robinson & Thurnher, 1979; Shanas, 1979). Principally, the separation of older people from their communities, from their families and from their friends has well documented negative effects on the health and wellbeing of both older people and their families (Bernoth & Dietsch, 2012). Visitation by friends and family provides a vital link to the outside world, and helps to counteract these negative effects (Harel & Noelker, 1982; Noelker & Harel, 1978; York & Calsyn, 1977). However, with increased travel times and distance, the potential for friends and family to visit falls and with it the frequency of visitation (Fukahori et al., 2007; Greene & Monahan, 1982; Hook, Sobal, & Jeffrey C. Oak, 1982; Minichiello, 1989; Port et al., 2001; Yamamoto-Mitani, Aneshensel, & Levy-Storms, 2002). With the closure of small facilities, particularly in rural areas, the potential for significant increases in travel times for much of the population are high.

Over the next 10-20 years however, the aged residential care sector is expected to experience a dramatic increase in demand. The New Zealand population is aging, and older people are increasing as a proportion of total population (Statistics New Zealand, 2000). Subsequently by 2026, and despite falling proportional demand for aged residential care, an anticipated 12,000 to 20,000 extra aged residential care beds will be needed to accommodate the increased number of clients (Grant Thornton, 2010). To meet this increased demand, many new facilities will likely need to be built.

The requirement to build these new facilities presents a unique opportunity for New Zealand to address poor spatial access to aged residential care. By prioritising the location of these new facilities so that they are more equitably distributed among the population, travel times for people entering care, their friends and their family could be minimised. By identifying methods for optimising the locations of new facilities, the anticipated negative impact of facility closures could be reduced.

In recent years, geographic information science (GIS) methods have been used in a myriad of applications to investigate and address inequity in spatial access to both health care and non-health care facilities (Cromley & McLafferty, 2002). However, there have been very few published applications of GIS methods to studies of spatial access to ARCFs, and fewer still investigating where to place future facilities. This thesis intends to investigate therefore, how GIS methods can be used to assess the equity of current ARCF locations in New Zealand and identify potential locations for ARCFs in 2026, so that spatial accessibility is maximised.

## 1.2. Research question

In implementing this research the following research question will be asked:

*to what extent can geographic information science (GIS) methods be used to assess current and identify and assess potential future locations of aged residential care facilities in New Zealand?*

To help answer this central research question, four further sub questions are identified:

1. *What can GIS methods show us about the equity of the locations of aged residential care facilities in New Zealand?*
2. *How can GIS methods identify potential future locations that are suitable to providers for the placement of aged residential care facilities and where are these locations for New Zealand?*
3. *How can GIS methods identify, from the potential future locations, those that most optimally supply the population, and where are these locations for New Zealand given future demand projections?*

#### *4. Can GIS methods help to improve the equity of the distribution of locations of aged residential care facilities in New Zealand?*

To answer these questions, this thesis will use New Zealand's aged residential care sector as a case study and seek to identify potential and optimal locations for ARCFs that are suitable for people entering care and for aged residential care providers.

The thesis takes the position that poor spatial access to ARCFs is both a market failure in the economic sense and public health concern worthy of intervention. It makes the assumption that DHBs as contractors of aged residential care have or should have the utility to set spatial constraints on the locations of facilities contracted to provide aged residential care.

This intervention in the placement of facilities to enhance resident visitation is not a new idea, but the cost and difficulty associated with altering the location of facilities has meant that it has been considered a poor candidate for intervention (Port, 2004). With the anticipated increase in the number of people entering aged residential care and the expected need for many new facilities, New Zealand has a unique opportunity to move towards addressing inequalities in the distribution of ARCFs without moving any existing facilities.

### **1.3. Research objectives**

To generate useful outputs for DHBs and answer the research questions, three interdependent objectives were identified:

1. Describe and measure the current accessibility of aged residential care facilities
2. Identify areas that are likely to be suitable to providers for the placement of aged residential care facilities in New Zealand
3. Determine where the new facilities should go so that spatial accessibility is maximised.

With the first objective, this thesis intends to describe and measure the spatial accessibility of ARCFs in New Zealand. By doing so areas where spatial accessibility is inequitable can be identified to provide baseline spatial accessibility measures against which the new locations can be compared.

With the second objective, this thesis intends to engage with providers of aged residential care to identify potential locations which could be suitable for the placement of ARCFs. Through engaging with providers, it is hoped that a balance can be struck between the business realities of the aged residential care sector and the health-maximising intentions of the public health system in New Zealand.

With the third objective, this thesis intends to identify from the potential locations, those which would most optimally serve the spatial needs of the population and minimise travel time for friends and family. It is hoped that through the identification of these new facility locations, the equity of the distribution of locations of ARCFs in New Zealand can be improved.

## **1.4. Overview of thesis**

The thesis is divided into eight chapters. In the next chapter, the thesis will explore geographic literature on measuring geographic access to health services both internationally and in New Zealand. The chapter will begin with an overview of the New Zealand context for the provision of ARCFs. The chapter will then move on to a definition and brief exploration of the concept of access, investigate studies of geographic access to ARCFs specifically, and then examine how previous research has sought to address geographic access inequity through the targeted placement of facilities using GIS.

The methodology chapter will summarise and evaluate the methods used in similar applications to identify methods most appropriate to this context. Divided into three parts, the chapter will explore potential methods for addressing each of the three objectives presented by this research. The chapter will describe and evaluate for application to this study [1] the suitability of methods used to measure potential spatial access of health care facilities, [2] common GIS-based methods for identifying areas matching specific spatial criteria and [3] common GIS methods for selecting optimal facility locations within an existing market.

The methods chapter will describe the methods used in the thesis. As with methodology, this chapter will be split into three parts, each describing the methods used to address each of the objectives presented by this thesis.

The data chapter will describe the data used in the thesis. The chapter will detail data sources, processing and, where appropriate, the rationale for using particular data sources over others.

The results chapter will then present the findings from this thesis. As with the methodology and methods chapters this chapter will be split into three parts and present the results of [1] the spatial accessibility measurement, [2] the analysis to identify locations suitable for the construction of ARCFs and [3] the analysis to choose optimal future locations.

The discussion chapter will then discuss the results. This chapter will consider the results in the context of the aged residential care in New Zealand, and evaluate the appropriateness of the methods used to the application.

Finally, the conclusions chapter will present the findings of the thesis and make recommendations for future research.



## 2. Literature

This chapter explores in more detail the New Zealand context for the provision of ARCFs, the falling proportional demand and the anticipated future increases in total demand. The chapter will then explore definitions of the geographic concepts of access and spatial access in section 2.2. After establishing an understanding of spatial and aspatial access, this chapter will then explore geographic literature on measuring spatial access to health services internationally and in New Zealand and investigate studies of spatial access to ARCFs specifically. This chapter will then examine how previous research has sought to address inequities in spatial access through the targeted placement of facilities using GIS. The chapter is summarised in section 2.5.

### 2.1. Context

To understand the setting in which this study operates, some consideration needs to be given to the context of the aged residential care sector in New Zealand. This section will provide a brief overview of the current aged residential care sector and investigate predictions for future demand growth.

In New Zealand, predominantly private and not-for-profit aged residential care providers are contracted by the DHBs on behalf of the Ministry of Health (MOH) to provide institutional care for older people with a DHB-assessed high dependency (Grant Thornton, 2010). If an older person meets the dependency criteria to enter into aged residential care, they may choose to receive the authorised services from any provider that supplies the type of care they require on the condition that the provider has a vacancy and approves the prospective resident (Grant Thornton, 2010). Older people without assessed high dependency can also enter ARCFs but are not eligible for government subsidy (Ministry of Health, 2011b).

Providers can be licensed to provide one or more of the following types of care at a given facility: rest home, continuing care hospital (also known as *aged care hospital*), psychogeriatric, and dementia care (Ministry of Health, 2011b). Facilities licensed for rest home care provide residential care for people with high dependencies that do not require specialist 24-hour medical care. Continuing care hospitals provide care for patients with high dependencies that generally require 24-hour nursing supervision. Secure dementia care facilities provide specialised residential care service for people with dementia. Psychogeriatric care facilities provide care for residents with an organic illness at the extreme end of dementia and who are defined by clinicians as having behavioural and psychological symptoms of dementia (BPSD). Additionally, a small minority of the resident population are younger people with physical impairment for whom alternative care cannot be found (Grant Thornton, 2010).

In addition to contracting with aged residential care providers within the DHB to provide the necessary care, DHBs are responsible for assessing older people's need for care, facilitating entry into a facility, subsidising their care within the facility, and ensuring there is sufficient supply of care beds for their region (Ministry of Health, 2011b). The aged related residential care contract (ARRC) signed between the DHB and providers enforces a national standard of services that are provided to residents in long-term residential care (Grant Thornton, 2010). Renegotiated each year, the ARRC stipulates the level of government subsidy paid to providers and the responsibilities of the provider, the client and the DHB.

Over 42,000 people are admitted into aged residential care each year (New Zealand Labour et al., 2010). To supply this demand, there were 683 ARCFs in New Zealand in 2011, containing a combined total of 34,709 ARCF beds (Ministry of Health, 2011a). Fifty six percent of the aged residential care bed stock were rest homes beds, 30% continuing care hospital beds, 8% secure dementia care beds, and 6% were psychogeriatric or younger physically impaired beds (Grant Thornton, 2010).

While the basic design of the sector has remained unchanged over the last decade the demand for facilities has undergone considerable change. Most prominently, the proportion of the older population receiving aged residential care has decreased. This decrease has been associated with several factors including: the rising availability of alternative types of care, such as home and community care services; older people remaining in good health and independent longer; and tougher functional and funding thresholds for subsidised care eligibility (Boyd et al., 2011). These changes have seen the make-up of the resident population change considerably: with residents having much higher levels of dependency on average and shorter lengths of stay (Boyd et al., 2009). However, for older people with high dependency, very few alternative options exist.

The falling demand in turn has pressure on supply. The migration away from aged residential care services by many older people with lower dependency has meant some facilities have struggled to attract enough clients to be economically viable. This has been compounded by largely static levels of government subsidy. The low level of subsidy has also meant that many smaller rest homes are becoming or have become economically unsustainable. For large review commissioned by District Health Boards New Zealand and the New Zealand Aged Residential Care Association, Grant Thornton (2010) identified a minimum operation efficiency level of 80 beds, below which providers would struggle to develop sufficient economies of scale. Over half of current facilities have fewer than 50 beds.



Further, low financial returns have discouraged private providers from investing in new facilities except in areas where there is the opportunity to make money from resident co-payments. The overall level of investment in new building stock is low, with only 19% of the facilities undertaking new development within the last 10 years (Grant Thornton, 2010). These developments have primarily (74%) been co-located with retirement villages and aimed at those with the means to make private contributions towards their accommodation and services. A minority proportion has been undertaken by not-for-profit organisations. Grant Thornton (2010) found that 43% of all facilities (and 58% of facilities built in the last decade) charged some of their residents extra fees for additional services - double the number that charged in 2006. Consequently, around half or all building stock is over two decades old (Grant Thornton, 2010).

Despite the proportional fall in demand, overall demand for aged residential care in New Zealand is forecasted to rise dramatically over the next two decades (Grant Thornton, 2010). In developed countries around the world, adults 80 years and older are both proportionally the highest users of aged residential care and represent the fastest growing population segment (Boyd et al., 2011; Christensen, Doblhammer, Rau, & Vaupel, 2009). The same applies to New Zealand (Statistics New Zealand, 2000). The total population of New Zealand is expected to grow by 20% between 2006 and 2026, while the over 65 population is estimated to rise by 84% and the over 85 population is expected to double.

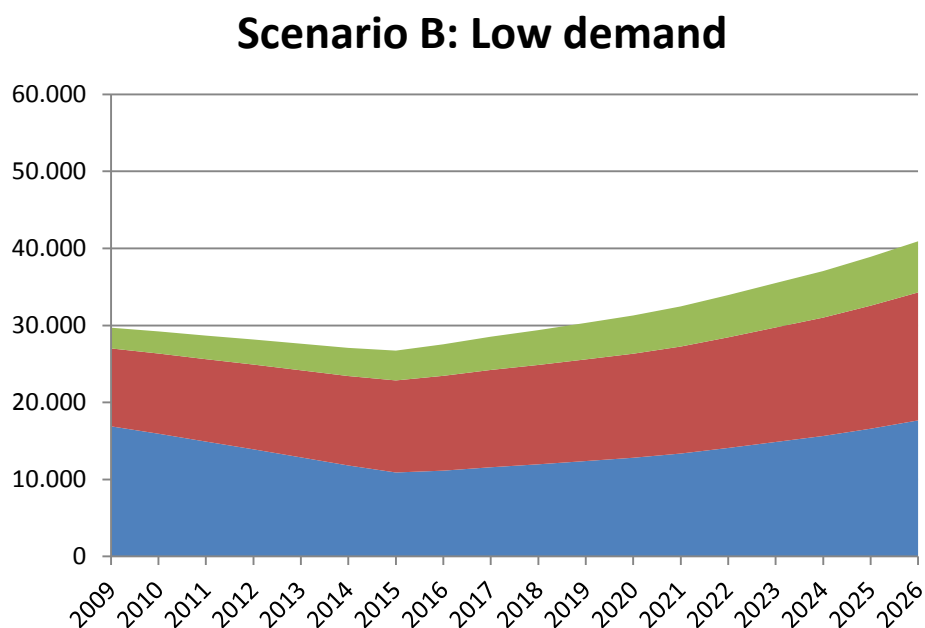
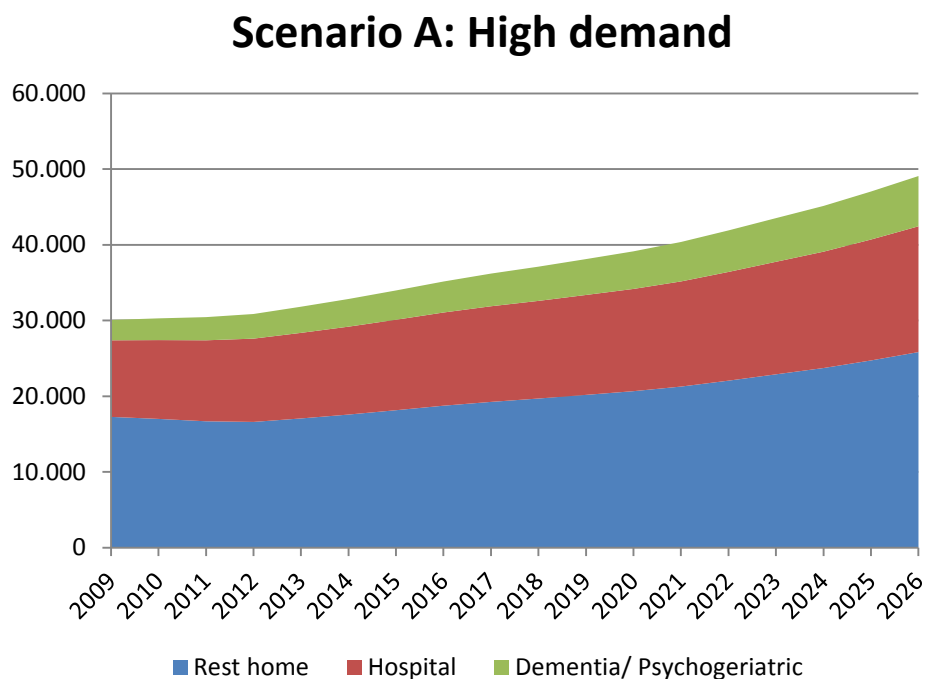
To quantify the impact of this increase in demand, Grant Thornton (2010) developed detailed projections of the number of ARCF beds required between 2009 and 2026. The review found that the proportional decline of rest home demand is expected to plateau between 2012 and 2015 and from there remain constant until at least 2026. Assuming that the current trends in preference for given types of services and utilisation of alternative care arrangements remain, no extensive technological improvement in provision of care occur, there are no changes to policy settings such as the NASC threshold and the income-asset test thresholds, and no change in price, Grant Thornton (2010) estimated that by 2026 between 12,000 and 20,000 extra ARCF beds will need to accommodate the demand.

Demand for hospital bed days was assumed to be less affected by economic drivers and alternative services, as those requiring such services are more likely to take them up than stay home (Grant Thornton, 2010). The demand therefore was expected to rise in line with population ageing and growth. Likewise demand for dementia beds was assumed to not respond to economic drivers. Internationally there have been substantial observed increases in demand for dementia care in recent years (Hogan, 2004; Macdonald & Cooper, 2007). Grant

Thornton assumed this trend would continue, leading to a demand increase of 160%, or 250 additional dementia beds every year. Demand for psychogeriatric care and young physically impaired services were assumed to only respond to changing population demographics (Grant Thornton, 2010).

Grant Thornton (2010) presents two scenarios for future demand: Scenario A - which assumes the rest home utilisation rate will decrease until around 2012, after which utilisation will increase in tandem with the increasing population; and Scenario B - which assumes the rest home population utilisation rate will continue to decrease until 2015 before increasing with population (Grant Thornton, 2010). Demands for other forms of aged residential care were kept the same between the scenarios. The resulting number of ARCF beds by year and scenario are presented below.

Figure 1: Projected demand for ARCF beds by scenario



Data from the New Zealand Aged Care Association (Personal Communication).

Under Scenario A, demand for aged residential care will begin to increase substantially from 2012. The capacity of current aged residential care stock will be exhausted by 2014. By 2026, 52,000 beds will be required.

Under Scenario B, total aged residential care demand will continue to decline until 2015, and then start to increase once more. The increase in overall bed numbers is considerably less than

Scenario A, yet there is considerable change in the service mix. Current capacity will be exhausted in 2021. By 2026, 44,000 beds will be required. As neither scenario was identified as being more likely than the other, both scenarios will be modelled by this study for 2026.

## 2.2. Defining access

As this thesis intends to investigate the potential for GIS-methods to improve the spatial access to aged residential care facilities in New Zealand there needs to clarity around what access means. The concept of access has long been an important consideration in health care policy. Access to health care is commonly described as "people's ability to use health services when and where they are needed" (Cromley & McLafferty, 2002). People's ability to use theses health services can be impeded by many different barriers, of which geographic barriers are just a subset.

Many authors have sought to describe access by dissecting it into smaller, more manageable concepts, commonly distinguishing between spatial access and non aspatial access (see Aday & Andersen, 1974; Gulliford & Morgan, 2013). Penchansky and Thomas (1981) provided the first, and since most commonly used, comprehensive definition of access for health care policy. Their taxonomic definition disaggregated access into five categories:

- 1) Availability – the relationship of the volume and type of health service to the clients' volumes and types of needs;
- 2) Accessibility – the relationship between the location of the service (supply) and the location of the clients;
- 3) Accommodation – the relationship between the organisation of service allocation (operating hours etc.) and the clients' ability to accommodate to this allocation and their perception of its appropriateness;
- 4) Affordability – the relationship between the prices of services and the clients' ability to pay; and
- 5) Acceptability – the relationship of the personal and practice characteristics of providers and the clients' attitudes, as well as the attitudes of providers about acceptable personal characteristics of clients. (Penchansky & Thomas, 1981)

Within their definition, Penchansky and Thomas draw a fuzzy divide between spatial and non-spatial categories. The spatial nature of *accessibility* within this definition is largely self-evident – large distances or required travel times between client and facility are a clear spatial barrier. *Affordability*, *acceptability* and *accommodation* are predominantly non-spatial in nature and reflect cultural and socio-economic factors (Bagheri, Benwell, & Holt, 2005). However, barriers

to *availability*, such as fully-booked health facilities or insufficient service levels, can very conceivably have spatial implications (Guagliardo, 2004).

In a similarly formative work on geographic access to health care, Joseph and Phillips (1984) dissect access into *locational* and *effective* – drawing a stronger divide between spatial and non-spatial dimensions of access. In their taxonomy, *locational* access mirrors the accessibility category of Penchansky and Thomas, describing the location of the service relative to the location of the client. *Effective* access on the other hand describes the social, financial and practical barriers to services, and can be seen to correlate well with the other four Penchansky and Thomas categories.

Likewise, Khan and Bhardwaj (1994) split access into spatial and aspatial categories. The authors defined the term *geographic access* as access which is conditioned by space or distance barriers/facilitators and the term *social access* to describe access which is conditioned by non-geographic barriers/facilitators.

At the same time, the spatial-aspatial dichotomy was being developed, many authors noted that the definition of access is complicated further by another dimension of meaning: access can be used to refer to the ‘potential’ for entry into the health system, or it can be used to refer to the ‘realised usage’ of the health system (Aday & Andersen, 1974; Aday & Anderson, 1981; Barnett, 1978; Joseph & Bantock, 1982). In this sense, access is both a noun referring to potential for healthcare use and a verb referring to the act of receiving or using services (Guagliardo, 2004).

Khan and Bhardwaj (1994) sought to bring these two dimensions together in a single model. The authors developed ‘a typology’ of access, which combined the two principal dichotomies, spatial-aspatial and potential-realised, in a single framework.

Figure 2: A typology of access

	Spatial	Aspatial
Potential	I Potential Spatial/ Geographic Access	II Potential Aspatial/ Social Access
Realised	III Realised Spatial/ Geographic Access	IV Potential Aspatial/ Social Access

(Khan & Bhardwaj, 1994: p.70)

This model allows for clear differentiation between (I) potential spatial access, (II) potential aspatial access, (III) realised spatial access and (IV) potential aspatial access.

The term *spatial accessibility*, referring to a combined measure of Penchansky and Thomas's *accessibility* and *availability* has found favour with health geographers in describing potential and realised spatial access to health services (Guagliardo, 2004; Luo & Qi, 2009; Luo & Wang, 2003; Salze, Banos, & Oppert, 2011; Wang & Luo, 2005; Yang, Goerge, & Mullner, 2006). Proponents state that while differentiating between the two is necessary in some instances, measured together they often provide a more appropriate conceptualisation of spatial access (Guagliardo, 2004).

### **2.3. Spatial accessibility of health care services**

Spatial accessibility has long been recognised as a key barrier to healthcare utilisation. Since the 1960s, there has been a proliferation of studies investigating the spatial accessibility of various health services to identify areas of provider shortage and inequity. Statistics, mapping and GIS have been employed to study the relationships between the location of health services and population distribution (Cheng, 2010). However, advances in personal computing power, and the development of sophisticated GIS methodologies and 'off the shelf' software packages have lead meant the volume of GIS contributions have increased dramatically in recent years (Cromley & McLafferty, 2002). As such, GIS-based studies of spatial access to health care are common in the geographic and public health literature (see Higgs, 2004, 2009). Numerous analyses investigating and measuring potential and realised spatial accessibility to most forms of health services and facilities have undoubtedly been published.

With the variation in subject matter, has come variation in techniques for measurement. Critical to analysing spatial accessibility is the identification of a method for measuring access that is appropriate for the context. GIS-based studies have typically used one of two broad methods: area-based measures and impedance-based measures.

Area-based methods typically describe for pre-defined areas (such as for states, towns or other physical, political or administrative units) the ratio of population need to services available. Area-based measurements provide good comparison between larger areas and the resultant figures are easy to interpret for policy makers and subsequently are often used to identify underserved areas and set targets for access. However, supply ratios do have considerable limitations. They do not account for 'border crossing', whereby users might access services in a neighbouring area, the effect of which can be especially pronounced in smaller areas. They also do not account for variation in accessibility within areas and they do not report on any measures of travel impedance. However despite this these limitations, their ease of use and

interpretation has meant they are likely the most commonly used spatial access measure (McGrail & Humphreys, 2009).

Impedance-based measures describe the impedance (distance or travel time) between the population and health care services. Impedance methods can take many forms. The most simple and formerly the most commonly used is straight-line (or Euclidean) distance between a population and its nearest service point. Straight-line distance however does not account for the distance and travel time of the actual travel path required. The solution to this is to assess travel time along a transportation network between population and nearest service. This method, network impedance (travel time or distance) to nearest service has been used in many studies (Guagliardo, 2004). The principal limitation of this method is that it is a poor measure of the availability of a health service as the nearest provider may not have the capacity to provide the service.

Some methods apply a combination of both area-based and impedance-based measures. For example, average network impedance to all services. In this method, the travel impedance from a population point to all services within an area (country, state, administrative unit etc.) is summed and averaged. The benefit of this method is goes some way to including availability by taking into account all available service points. The two primary limitations with this method is it that it does not allow for border-crossing, and for large areas it over-weights the influence of services near the periphery of the study area.

More complex impedance-based measures also exist. Gravity models are the most common of these complex methods. Gravity models measure the potential interaction between a population point and all the service within a reasonable distance, discounting the potential influence with increasing distance or travel impedance (Guagliardo, 2004). Like average network impedance to all services, gravity models account for multiple service points but only those within a reasonable distance, allowing for a strong measure of availability. For this reason, they are sometimes referred to as cumulative opportunity measures (Guagliardo, 2004). The principal limitation with this method is that gravity models require a distance decay coefficient be calculated through empirical investigation for each service type and population prior to the analysis (Talen & Anselin, 1998). Applications of this method are numerous (Khan, 1992; Lowe & Sen, 1996; Schuurman, Bérubé, & Crooks, 2010).

Two-step floating catchment is a method developed by Lou and Wang (Luo & Wang, 2003; Wang & Luo, 2005) for measuring spatial accessibility to primary care services. With this method a provider to population ratio is calculated for each administrative unit containing a service location. The number of providers within each administrative unit is divided by the

population within a defined travel time ( $x$ ) from the centroid of the unit. The ratio is then assigned to each population point within the travel time ( $x$ ). All the provider-to-population ratios assigned to each population are summed to provide a provider-to-population ratio for each population point. The benefits of this method are that it allows for border crossing and that the resultant data is in the form of provider to population ratios, making for easy interpretation for policy makers. The main limitation is that population points beyond  $x$  travel time from a service point are assumed to have an access score of zero (Guagliardo, 2004). Despite its recent development, this method has been implemented in several studies of potential spatial access to health services (McGrail & Humphreys, 2009; Yang et al., 2006).

### **2.3.1. Potential spatial access to health services in New Zealand**

Potential spatial accessibility has been investigated for several service types in New Zealand. The studies typically identified inequities in access by region, rurality, DHB, and deprivation.

Brabyn and Skelly (2001, 2002) investigated the geographic accessibility of public hospitals in New Zealand using impedance-based measures. The authors investigated travel time from the centroid of each meshblock in New Zealand to the closest public hospital. They found considerable variation in average distance and average travel time when aggregated by DHBs, with Southern DHB (formerly Otago and Southland DHBs), Northland and Tairāwhiti DHBs returning travel times over 45 minutes.

Brabyn and Barnett (2004) applied three methods to their study of geographic access to general practitioners (GPs) in New Zealand: provider-to-population ratios, network impedance to closest service and an impedance-based allocation method. The third method was a solution to the capacity constraint issue present in other impedance-based methods. Demand (population) was allocated to general practices based at an expected capacity (1400 patients per GP), and average travel time for each population point was returned. The authors found that rural areas with lower populations had poorest spatial accessibility. Territorial authorities the highest concentration of affluent areas as measured by the New Zealand Deprivation Index (deciles 1-3), had shorter travel times than more deprived populations (deciles 8-10). They also found that compared with the closest service analysis, the population with travel times over 30 minutes rose 80% with the allocation method, from 71,000 to 128,000, suggesting capacity constraints had a large effect on accessibility.

Brabyn and Beere (2006) investigated the impact of health reform in New Zealand on spatial access to hospital emergency departments. The authors compared network impedance (travel time) to closest emergency department from meshblock centroids in 2001 with the average travel time in 1991. Brabyn and Beere found that the average travel time increased overall.



Several DHBs increased dramatic travel time increases, primarily Tairāwhiti where average travel time increased by 22 minutes, due to the closure of a hospital. Travel times over 60 minutes also increased considerably for Otago and Southland (now Southern) DHBs and nearly half (43%) the population of Northland had ED travel times over an hour. Beere and Brabyn also addressed geographic accessibility of maternity units (Beere & Brabyn, 2006). The authors found considerable variation between regions in New Zealand, with Waikato having the largest population with travel times over an hour, due to their large rural population.

Bagheri et al (2005) investigated the spatial accessibility to primary health care services in the Otago region using a network impedance (travel time) to closest service analysis. Like Brabyn and Skelly (2001, 2002) and Brabyn and Barnett (2004), the authors measured travel time from meshblock centroids to service location. They found people living in the northern and central parts of Otago had much poorer access than in other regions.

Geographic access to termination of pregnancy services was investigated by Silva and McNeill (2008). Travel times were calculated from the principal hospital in regions without a termination of pregnancy service to the nearest service provider. Where women were known to be referred to more distant providers, a range of different referral pathways were modelled and the average taken. The authors found that regions without service providers had lower uptake, and a higher than average Māori population.

Of interest to this thesis is that considerable variation in spatial access was demonstrated for each health service studied. As was identified in the introduction, rural area and less affluent areas might potentially have poorer access to ARCFs in New Zealand (New Zealand Labour et al., 2010). Both of these factors were associated with poorer access to other health services. Five of the six studies identified here identified rural areas as having poorer access than urban areas, and affluence as measured by the New Zealand deprivation index was associated with poorer access to GPs.

### **2.3.2. Spatial access to aged residential care facilities (ARCFs)**

#### **2.3.2.1. Potential access**

Despite the large number of studies on potential spatial access to health care services (see Higgs, 2004, 2009), there exist few studies on access to ARCFs. In the United States, Love and Lindquist (1995) used a combination of area-based methods and Euclidean catchments to describe the geographic accessibility of aged care hospitals in Illinois. Their analysis showed that while eighty percent of the population was within 8km of an aged care hospital, there was marked differences in the accessibility for people living in metropolitan areas compared with

those living in non-metropolitan areas. 80% of the population living outside of metropolitan areas had to travel over 18km and 45% had to travel more than 41km.

In Australia, Hugo and Aylward (1999) explored the access to ARCFs in non-metropolitan South Australia. The authors used two impedance-based measures of accessibility: network impedance (distance) to closest provider, and a count of population within 100km and 200km of providers. Next, population distribution was modelled across the study area, and provider to population ratios calculated for each service catchment. Results from their analysis suggested that older people's access to care was just at, or slightly below, policy targets, and below that of metropolitan South Australia. Access was better to providers providing lower levels of care than those providing higher care.

Also in Australia, Gibson, Braun and Liu (2002) used area-based methods to identify the equity of the spatial distribution of aged care services nationwide. The authors investigated the distribution of aged care services, including residential, by four geographic categories: capital cities, other metropolitan areas, rural areas and remote areas. Most residential care facilities were located in capital cities and subsequently capital cities had the highest provider-to-population ratios. Many of the rural areas had lower than average supply. Gibson and colleagues noted however that many of these residentially under-served areas were supplemented with higher than average levels of alternate aged care services.

Cheng, Wang and Rosenberg (2012), building on the work by Cheng (2010), investigated the spatial accessibility of residential care services in Beijing, China. The aim of the project was to identify underserved areas to support the case for 'rational allocation' of aged residential care resources. Their analysis combined two measures of spatial access: network impedance (travel time) to closest facility and two-step floating catchment. The authors found that sub- and extra- urban areas had better access than the central city, but the central city had higher access than the city outskirts. Furthermore, when employing the two-step floating catchment method to better account for availability, shortages were identified in regions where aged residential care 'hotspots' exist.

In New Zealand, Joseph and Chalmers (Al Chalmers & Joseph, 1998; Joseph & Chalmers, 1995, 1996) published several papers on the changing geographies of aged care services and the elderly population in Waikato in the 1980s and 1990s. These studies, which included measuring a combination of potential and realised access, considered the 'in-place' experience of growing old in rural communities (Joseph & Chalmers, 1995). The studies also paid attention to the availability of aged residential care and its implications to rural elderly, finding

for residents of smaller towns, moving to aged residential care would require them to move to unfamiliar communities (Joseph & Chalmers, 1995, 1996).

Joseph and Chalmers (1996) was solely concerned with the effect of restructuring in the aged residential care and the evolving geographies of the elderly in Waikato over the period 1981-91. The authors were interested in how the distribution of elderly populations and ARCF beds evolved in the wake of the privatisation of the long-term care market in New Zealand. The authors found a considerable imbalance in the supply of ARCF beds between urban and rural areas in Waikato. Nearly all urban areas in Waikato were found to have increased numbers of aged-residential care beds, led primarily by public sector initiatives, while rural communities generally suffered a reduction in the number of beds. Almost all hospital-level care was found to be concentrated in Hamilton and the larger towns in the Waikato. The authors noted that the future was particularly bleak for elderly residents of smaller rural towns, where they were faced with relocation to unfamiliar communities should they require aged residential care.

Each of these studies identified that there was variation in the spatial access to ARCFs similar to what has been observed for other health services. Joseph and Chalmers (1996) being the sole study identified of potential spatial access to aged residential care in New Zealand and which showed that the privatisation of ARCFs was associated with an increases in the number of beds in urban areas and a decrease in the number in rural areas is of particular interest. If the decreasing access for populations in rural areas observed by Joseph and Chalmers is true nationally, then there is potential for this study to identify considerable inequity in the locations of ARCFs in New Zealand.

#### **2.3.2.2.            *Realised access***

A greater number of studies concern themselves with measuring realised spatial access to aged residential care (see Boyd et al., 2011; Mor, Sherwood, & Gutkin, 1986). For many of these studies, spatial barriers were considered alongside non-spatial barriers, when analysing realised access. Of particular interest to this thesis are the studies which considered spatial barriers to visitation (Fukahori et al., 2007; Hook et al., 1982; Minichiello, 1989; Port, 2004; Port et al., 2001; Yamamoto-Mitani et al., 2002).

In perhaps the seminal piece of research on the subject, Hook, Sobal and Oak (1982) investigated factors associated with frequency of visitation to nursing homes in the United States. Data was gathered through a questionnaire administered to all visitors entering the home during visiting hours. The authors found that distance travelled was the most important factor in determining frequency of visitation by a very considerable margin. Hook and

colleagues suggested that site location for nursing homes “should minimise distances between the home and the residences of relatives (Hook et al., 1982: p.427)”.

In a similar study undertaken in Australia by Minichello (1989), the author interviewed residents of ARCFs and asked them to name all the people they considered to be part of their social networks, their relationship to themselves, where they lived and how often they visited them. Minichello found that distance was significantly negatively correlated to the frequency of visitation.

Fukihori et al. (2007) studied the factors related to relating to the frequency and length of visits to elderly residents of nursing homes by family members in Japan. They found that distance to nursing home from family members was negatively related to the frequency of visits. They also found that family members who had travelled further were more likely to stay longer, and were reasoned by the authors to be using the time to gather information about and communicate with the residents.

Similarly, an American 5-year longitudinal study of family-member caregivers who moved their relatives from home into a nursing home found that travel commute time was closely associated to visitation frequency (Yamamoto-Mitani et al., 2002). In the analysis, caregivers were group by frequency of visitation: weekly, bi-weekly and daily. The distance to the nursing home from the caregiver's home was associated with the frequency of visitation. The average commuting time of the group who visited daily was around half the duration of the group that visited bi-weekly, and a quarter of the duration of that of the weekly visitors.

Another manner of analysis used 'Support Network Proximity' as a predictor variable. A count of the number of people in the resident's social network (defined by five categories: spouse, siblings, children, other relatives, and friends/neighbours) that live within a one-hour drive of the facility was used by Port et al. (2001). The author found through interviews with 1,441 'significant others' in residents' lives, that for both pre- and post-admission into a facility, support network proximity was significantly positively correlated with visitation.

Interestingly, not all studies have encountered distance as an inhibitor. One telephone-based interview study conducted by Port (2004) found transportation difficulty and not distance was the variable most predictive of visitation frequency. The author found that while travel distanced to the facility was negatively related to visitation frequency, when the final regression model was applied, transport difficulty remained significant but transport distance did not.

## **2.4. Improving spatial access to health services with GIS**

A large amount of previous research has sought to address inequities in spatial access through the targeted placement of facilities using GIS methods (Cromley & McLafferty, 2002). These studies can be broadly categorised into two categories: studies identifying potential facility locations from set criteria, and studies identifying locations to most optimally supply demand. Literature conforming these two categories is discussed below.

### **2.4.1. Identifying potential locations**

Studies that identify potential locations for health care services fall within the group of analyses collectively referred to as land-suitability analyses. Defined most broadly, land-suitability analyses aim to identify the most appropriate spatial pattern for land use according to a set of requirements, preferences or predictors of some activity (Hopkins, 1977; Malczewski, 2004). GIS-based applications of land-suitability analyses have been applied to many contexts from predicting wildlife behaviours (Doswald, Zimmermann, & Breitenmoser, 2007) to siting future landfills (Şener, Suzen, & Doyuran, 2006). The full range of these analyses has been summarised elsewhere (Malczewski, 2000, 2004).

A small proportion of these analyses have been conducted for the purpose of identifying suitable sites for health services or facilities (see Carlson, York, & Primomo, 2011; Kar & Hodgson, 2008; Sharmin & Neema, 2013; Vahidnia, Alesheikh, & Alimohammadi, 2009). Several analyses have been undertaken for identifying hospital locations. For example, Sharmin and Neema (2013) used a GIS-based multi-criteria analysis to choose potential locations for new hospitals in Dhaka City, Bangladesh. The authors identified five necessary criteria for the location of a new hospital in the context of the highly densely populated city: within 20 metres of a road, within 60m of a water body, greater than 50m from an educational institution, greater than 100m from industrial areas, and at least 100m from the nearest hospital. Attribute maps for each of these criteria were developed and overlaid in a GIS, and areas which met each of the criteria were identified as potentially suitable locations.

Two land-suitability analysis were identified that sought to identify potential locations for ARCFs. In 2009, a detailed site selection process was undertaken on to select the location for a new State Veterans Home in Southwest Montana (SW Montana Veterans' Home Site Selection Committee, 2009). A site selection committee was established to evaluate potential sites and decide on a final location for the facility. Their site-selection process can be observed from a series of meeting minutes and associated documents published online (Montana State Government, 2011; SW Montana Veterans' Home Site Selection Committee, 2009). The committee developed a list of selection criteria and weightings by which to assess suitability of

potential sites (SW Montana Veterans' Home Site Selection Committee, 2009). However, the results of the exercise were not published so the efficacy of the activity cannot be assessed.

A similar procedure was undertaken in Minnesota in 2009. Contractors Engan Associates and Ulteig (2009) conducted a community identification study for a new veterans' home on behalf of the Minnesota Department of Veterans Affairs, Minnesota Veterans Homes in order to identify communities within the State where it would be most feasible to locate a new facility. This analysis differs from the example in Southwest Montana in that it is not seeking to identify an exact site, instead it looks to identify the community or region which would be suitable. In this regard its aims are closer to that of this study.

#### **2.4.2. Identifying optimal locations**

With the improvements in computing power and GIS software that have heralded the current proliferation of studies into the spatial access of health services has come the capacity for more sophisticated GIS applications and tools. One such tool is location-allocation modelling, which allows the user to locate facilities in such a way that supplies the demand (population) most efficiently. In effect, location-allocation provides a framework for improving access to services by nominating new facility locations to improve existing service systems (Rahman & Smith, 2000).

There are many different mathematical formulations of location-allocation models, designed for different applications, that have been explained in great detail elsewhere (Farahani, Asgari, & Heidari, 2012; Murray, 2010; Şahin & Süral, 2007). Most commonly however, these models fit into three primary categories: [1] p-median models, which generate facility locations and allocate demand to facilities in a way that minimises total or average travel impedance (time or distance); [2] location set covering problems, which locates facilities and allocates demand in such a way that all demand points are served by at least one facility within a maximum impedance (travel time or distance); and [3], maximal covering location problems, which locates a fixed number of facilities and in such a way that as few people as possible are outside the desired service distance (Rahman & Smith, 2000). The choice of model depends on the goal of the location-allocation analysis.

Location-allocation analyses have had widespread use in health applications. They have been commonly used in the developing world where the need for large numbers of new facilities is more regular (Oppong, 1996; Rahman & Smith, 2000). Applications have included locating primary care facilities in Nigeria (Ayeni, Rushton, & McNulty, 1987), Ghana (Murawski & Church, 2009; Oppong & Hodgson, 1994) and Burkina Faso (Cocking, Flessa, & Reinelt, 2006). Elsewhere in the world, location-allocation has been used to identify optimal locations for

many service and facility types including: ambulance services (Berlin & Liebman, 1974; Henderson & Mason, 2005), blood donation services (Jacobs, Silan, & Clemson, 1996; Şahin, Süral, & Meral, 2007) and primary health facilities (Mohan, 1983; Shariff, Moin, & Omar, 2012). However, no examples were found that sought to choose optimal locations for ARCFs.

## 2.5. Summary

A large body of literature was identified that investigated the potential spatial access to health services internationally and in New Zealand. The New Zealand-based studies identified considerable variation in access between regions in New Zealand, in particular between urban and rural areas.

Despite the large number of studies into the potential spatial access of health services, comparatively few examples were found that investigated access to ARCFs, although each identified variation in spatial access to ARCFs similar to what has been observed for other health services. Of most relevance to this thesis, Joseph and Chalmers (1996) showed that the privatisation of ARCFs in Waikato, New Zealand was associated with an increase in the number of beds in urban areas and a decrease in the number in rural areas. If the decreasing access for populations in rural areas observed by Joseph and Chalmers is true nationally, then there is potential for this study to identify considerable inequity in the locations of ARCFs in New Zealand.

A considerably body of literature focussed on identifying potential locations for health services using GIS methods and selecting locations which most optimally supply the spatial requirements of clients. Two studies used GIS methods in selecting sites for future Veteran's Homes in the United States that were suitable to the providers, the State Veteran's Associations (Engan Associates & Ulteig, 2009; SW Montana Veterans' Home Site Selection Committee, 2009). However, no studies were found that used GIS to identify optimal locations for ARCFs so that spatial access for clients is optimised. There is therefore a considerable gap in the literature for research on improving access to ARCFs both in New Zealand and internationally.





### 3. Methodology

This chapter will summarise and evaluate the methods used in similar applications to identify methods most appropriate to the context of this study. Divided into three parts, this chapter will explore potential methods for addressing each of the objectives of this research. Part one will describe and evaluate the suitability of methods used to measure current potential spatial accessibility of health care for application to this study. Part two describes and evaluates common GIS-based suitability analysis methods used to identify areas matching specific criteria. Finally, part three will describe and compare location-allocation methods for locating new facilities within an existing market so that spatial access is optimised.

#### 3.1. Part 1: Measuring spatial accessibility

There is not a single, uniform measure for potential spatial accessibility. Rather there are a range of alternatives that seek to reveal spatial accessibility in the most appropriate way for their individual applications. The variation between applications means that there is not one method that is appropriate for all situations. The methods also differ greatly in complexity, with some requiring complex mathematical knowledge or sophisticated GIS skills, while others are simpler but are often more coarse in their estimations. Furthermore, the target audience plays a considerable role in determining the method used; while complicated mathematical techniques might be intuitive to mathematicians, they might not be so useful for policy or decision makers. Therefore, choosing an appropriate technique for the subject matter under investigation is of considerable importance.

As described in the literature review, GIS-based studies have typically used one of two broad methods: area-based measures and impedance-based measures. Area-based methods, typically describe for pre-defined areas (such as for states, towns or other physical, political or administrative units) the ratio of population need to services available. Impedance-based measures on the other-hand describe the impedance (distance or travel time) between the population and health care services. However, these two fields are not mutually exclusive, with some methods utilising a combination of both area-based and impedance-based measures.

##### 3.1.1. Area-based methods

Provider-to-population ratios are the simplest and most common spatial accessibility measure. Also called supply ratios, these ratios are the ratio of providers to population within a defined geographical area. They are generally expressed as:

$$A_i = \frac{y_i}{x_i}$$

where  $A_i$  is the spatial accessibility for the region  $i$ , and  $y$  is the the number of providers in the region and  $x$  is the population. Several variations on the provider to population ratios are commonly used in aged residential care literature; Gibson, Braun & Liu (2002) compared the spatial accessibility of aged care services in Australia by state and rurality largely using supply ratios. For nursing homes in the United States, the bed supply ratio is used to determine where underserved populations lie and to identify where new beds should be established (Washington State Legislature, 2003).

Area-based measurements provide good comparison between larger areas and the resultant figures are easy to interpret for policy makers and subsequently are often to identify underserved areas and set targets for access.

However, there are limitations with using provider-to-population ratios as measures of spatial accessibility. Firstly, they do not account for population border crossing, where the population of interest attends a facility in another region. Secondly, they do not consider variations in spatial accessibility within regions. And thirdly, by not quantifying travel time or distance for the populations, they can suffer from the modifiable areal unit problem (MAUP), wherein the results can vary considerably between regions due to size, number and configuration of the areas studies (Guagliardo, 2004).

### **3.1.2. Impedance-based methods**

There are many different impedance methods used in the potential spatial accessibility literature. Travel Impedance to the nearest facility is perhaps the most commonly used method in spatial accessibility studies of healthcare. It has been used extensively internationally and in New Zealand (Bagheri et al., 2005; Brabyn & Barnett, 2004; Brabyn & Skelly, 2001, 2002) to measure the spatial accessibility of health services. A variation of straight-line (or Euclidean) distance to nearest service, travel impedance to nearest provider uses calculations of travel time or travel distance along a transportation network to assess access. Impedance is calculated from a population point to the nearest facility. Depending on the population of interest and the availability and resolution of data, the population point might be a person's residence or a population point, such as a geometric centroid of an administrative unit.

In GIS applications, travel impedance to nearest facility is usually calculated using a technique often called least cost path analysis (LCPA). LCPA calculates the path of least resistance between two points along a network. Typically, the algorithm used is based off Dijkstra's (1959) algorithm which for a given source vertex (node) in the graph, finds the path shortest path (i.e. that path with the lowest cost) between that vertex and every other vertex, and

returns the sum of the path with the lowest cost overall. Travel impedance to nearest provider has been used internationally to analyse the spatial accessibility of aged residential care. Hugo and Aylward (1999) used least cost path analysis along a road network to calculate the travel distance from non-metropolitan population centres to the nearest ARCF. Love and Lindquist (1995) used distance to nearest facility as a measure of spatial accessibility to aged care hospitals in Illinois, USA.

The popularity of travel impedance to nearest provider as a measure of spatial access is due to three reasons. First, it is easy to implement in a GIS environment. Most major GIS software packages have the functionality to perform LCPA inbuilt or accessible through download and/or purchase. Second, a measure of spatial accessibility can be generated for every population point. This means for every item of interest, be it an address or a population centroid, a measure of spatial accessibility can be returned, which might be of particular interest in identifying areas with poor access. Third, the results of the analysis are easily interpreted by policy and decision makers. A travel time is interpretable by readers and does not require a sophisticated understanding of the context in the same provider-to-population ratios and ratios might.

The central limitation of travel impedance to nearest provider is the lack of a comprehensive availability component to the analysis. It is assumed that populations visit the nearest facility. Travel impedance to nearest provider is often used in studies of spatial accessibility in rural environments where facility choice is limited and the nearest facility is likely to be the one visited. However, other factors such have been shown to dictate facility visited. Fryer et al. observed that for rural Colorado if patients only visited their nearest physicians the demand on some of the facilities would have been so great as to be un-servable (1999). Multiple facilities within similar distances, such as might be found in metropolitan settings, are not reflected in the analysis.

### **3.1.3. Combination area and impedance-based methods**

Some methods apply a combination of both area-based and impedance-based measures. A similar method to travel impedance to nearest provider but with an incorporated measure of availability is average travel impedance to provider. In this method travel impedance from a population point to all services within an area (country, state, administrative unit etc.) is summed using an LCPA and averaged. The principal benefit of this method is goes someway to including availability by taking into account all available service points. The two primary limitations with this method is it that it does not allow for border-crossing, and for large areas it over-weights the influence of services near the periphery of the study area. The literature

search for this thesis, like previous literature searches (Guagliardo, 2004), found just a single example where this had been used in a health care setting (Dutt, Dutta, Jaiswal, & Monroe, 1986).

More complex impedance-based measures also exist. Gravity models are the most common of these complex methods. Gravity models, (also called potential models or cumulative opportunity models) like the average travel impedance to provider method, are combined measures of accessibility and availability. They attempt to "represent the potential interaction between any population point and all service points within a reasonable distance, discounting the potential with increasing distance or travel impedance" (Guagliardo, 2004: pp.4-5). This allows for a dependable measure of accessibility and availability that is appealing to health researchers. The formula for a basic gravity model is as follows:

$$A_i = \sum \frac{S_j}{d_{ij}^\beta}$$

where  $A_i$  is spatial accessibility for the population point  $i$ .  $S_j$  is service capacity at provider location  $j$ .  $S_j$  represents the measure of capacity for the facility type, in the case of aged residential care it would likely be beds.  $d$  is the travel impedance (time or distance depending on the metric desired) between  $i$  and  $j$ , and  $\beta$  is the change in difficulty as travel time or distance change. If summed provider capacity increases, or summed travel impedance decreases, spatial accessibility is improved (Guagliardo, 2004).

Gravity models have been used in spatial accessibility studies for some time. They were first developed by Hansen (1959) while creating a model for land use in Washington, DC. Joseph and Bantock (1982) were the first to apply gravity modelling to healthcare usage with their study of the physical accessibility to GPs in rural areas in Canada. Like for travel impedance to the nearest facility, where Fryer et al. (1999) demonstrated that without adjustment for demand, populations could be located to a facility in such numbers that demand could overwhelm the facility, this basic gravity model has no adjustment for demand. In applying Hansen's model to the study of spatial access to GPs Joseph and Bantock (1982) noted this issue and proposed a modified formula that includes a population demand adjustment factor:

First, a demand adjustment factor,  $V_j$ , was calculated with the following formula

$$V_j = \sum_k \frac{P_k}{d_{kj}^\beta}$$

where  $P_k$  is population at point  $k$ ,  $d$  is the distance between the population point  $k$  and provider location  $j$ .  $V_j$  effectively distributes demand in the same way the basic gravity model distributes provider supply. Joseph and Bantock's modified model is then formulated as:

$$A_i = \sum_j \frac{S_j}{d_{ij}^\beta V_j}$$

The principal limitation with this method is that the distance decay coefficient,  $\beta$ , varies with application and must be calculated through empirical investigation for each service type and population prior to the analysis (Talen & Anselin, 1998). Previous examples in the literature for similar situations could be used, but previous literature is (to my knowledge) nonexistent for aged residential care service applications internationally or more generally access to healthcare nationally. Furthermore, results from gravity models are not as intuitive to decision makers in the same way that more simple measures are.

Another complex method for measuring spatial accessibility to health services is two-step floating catchment area (2SFCA) analysis. The two-step floating catchment area method is a variation on the gravity model. The method was conceptualised by Peng (1997), expanded upon by Radke and Mu (2000) and then formalised as a method by Luo and Wang (Wei Luo & Wang, 2003; Wang & Luo, 2005). This method is somewhat unique in that while not initially conceptualised as such, it was developed into a method primarily for health care applications. Central to its design is an attempt to overcome two of the biggest issues facing spatial accessibility measures for healthcare studies: an included measure of availability and an attempt to overcome the issue of border crossing.

As indicated in the name, there are two necessary steps for calculating a spatial accessibility using two-step floating catchment. Firstly, for each provider location  $j$ , search all population points ( $k$ ) that are within a desired travel time ( $d_0$ ) from  $j$ . The provider-to-population ( $R_j$ ) can then be calculated for the provider catchment with the following formula:

$$R_j = \frac{S_j}{\sum_{k \in (d_{kj} \leq d_0)} P_k}$$

where  $P_k$  is the population of the population point  $k$ ,  $S_j$  is a measure of availability (i.e. physician F.T.E.s or hospital beds) at location  $j$ , and  $d_{kj}$  is the travel time between  $k$  and  $j$  (Luo & Qi, 2009; Luo & Wang, 2003). Secondly, for each population point  $i$ , search all physician locations ( $j$ ) that are within a desired travel time ( $d_0$ ) from  $i$ , and sum the provider-to-population ratios ( $R_j$ ) at these locations. A value for spatial accessibility,  $A_i^F$  can then be calculated for the population at population point  $i$ :

$$A_i^F = \sum_{j \in (d_{ij} \leq d_0)} R_j$$

where  $R_j$  is the provider-to-population ratio calculated in step one for physician location  $j$  whose centroid falls within the catchment centred at population point  $i$  ( $d_{ij} \leq d_0$ ), and  $d_{ij}$  is the travel time between  $i$  and  $j$  (Luo & Qi, 2009; Luo & Wang, 2003).

Having been designed primarily for measuring spatial access of primary health services, 2SFCA is naturally well suited to applications in health research: The resultant data are recognisable to policy and decision makers as provider-to-population ratios; they provide a combined measure of spatial accessibility and availability; and they are not constrained by geopolitical border crossing. As with other methods 2SFCA has some limitations, principal among which is that the travel impedance cut-off values are unnaturally sharp. This means that spatial accessibility at the edge of the catchment is the same as at the centre, but just over the edge it drops to zero (Guagliardo, 2004). Recent developments with the method have presented solutions to the using distance decay functions to more soften the effects of the hard cut-off (Luo & Qi, 2009; McGrail & Humphreys, 2009). Secondly, like with the coefficient necessary for gravity models, the cut-off value (and the distance decay functions in the improved model) is dependent on the situation at hand and needs to be generated from empirical research or perhaps from policy targets.

#### 3.1.4. Weighing up the alternatives

The measurement of potential spatial accessibility of aged residential care for this exercise is required to perform two functions. The first is simply to describe the current accessibility to determine the equity of current distribution and identify areas for improvement. The second is to provide a baseline against which to compare the distribution of the facility locations generated in part three of this thesis. Therefore, any spatial accessibility measurement methods used need to be suitable for application to the aged residential care sector in New Zealand and still of value when replicated with the different supply and demand levels of the future. The advantages and disadvantages of each method are summarised below (Table 1).

Table 1: Advantages and disadvantages of each spatial accessibility measurement method

Method	Advantages	Disadvantages
Provider-to-population ratios	<ul style="list-style-type: none"> <li>• Principally a measure of availability</li> <li>• Data can be of coarser resolution than other methods</li> <li>• Simple to generate</li> <li>• Easy for decision makers to interpret</li> </ul>	<ul style="list-style-type: none"> <li>• Does not take into account accessibility</li> <li>• Do not account for border crossing</li> <li>• Requires 'coarse' resolutions of data by necessity. Needs big regions to get a useable ratio</li> <li>• Do not consider variations in spatial accessibility within regions</li> <li>• Can suffer from the modifiable areal unit problem (MAUP)</li> </ul>
Travel impedance to nearest provider	<ul style="list-style-type: none"> <li>• Relatively simple to generate</li> <li>• Software has the built in functionality to perform the operation</li> <li>• Allows for aspatial accessibility measure to be generated for every population point</li> <li>• Easy for decision makers to interpret</li> </ul>	<ul style="list-style-type: none"> <li>• Does not account for availability</li> <li>• Distorted results in metropolitan areas</li> </ul>
Average travel impedance to all providers	<ul style="list-style-type: none"> <li>• Combined measure of accessibility and availability</li> <li>• Relatively simple to generate</li> <li>• Software has the built in functionality to perform the operation</li> <li>• Allows for aspatial accessibility measure to be generated for every population point</li> <li>• Easy for decision makers to interpret</li> </ul>	<ul style="list-style-type: none"> <li>• Limited application in the literature – limited knowledge of limitations</li> <li>• Do not account for border crossing</li> </ul>
Gravity model	<ul style="list-style-type: none"> <li>• Allows for aspatial accessibility measure to be generated for every population point</li> <li>• The adjusted gravity model accounts for accessibility and availability</li> </ul>	<ul style="list-style-type: none"> <li>• The distance decay coefficient, <math>\beta</math>, requires empirical research to generate</li> <li>• Resultant spatial accessibility value is not intuitive to decision makers</li> </ul>
Two-step floating catchment area (2SFCA)	<ul style="list-style-type: none"> <li>• Combined measure of accessibility and availability</li> <li>• Creates a spatial accessibility measure for every population point</li> <li>• Easy for decision makers to interpret</li> <li>• Allows for border crossing</li> </ul>	<ul style="list-style-type: none"> <li>• Complicated procedure</li> <li>• The cut-off value must be estimated from previous literature (which is almost non-existent) or generated from empirical research</li> <li>• Areas without facilities inside their artificial cut off period will have a value of zero – or will require a distance decay function to estimated from previous literature or generated from empirical research</li> </ul>

The literature review found no previous applications of gravity models or two-step floating catchment area methods on health services in New Zealand and no previous applications of either to the aged residential care sector internationally. As both rely on existing research to calculate values of functions within their formula or the researcher to undertake the research prior to calculating spatial accessibility it was decided that neither would be within the scope of this exercise. Furthermore, that the primary output of 2SFCA would be provider-to-population ratios, there were concerns that the findings from 2011 and the projected findings from 2026 would not be comparable as both the supply and the demand would be expected to change. The lack of previous application of average travel impedance to all providers and unknown limitations discouraged its use.

Therefore it was decided that in order to achieve measurement of spatial accessibility a combination of provider-to-population ratios and travel impedance to nearest provider would be used in this study. This combination has a substantial history in the literature. However, the identified limitations must be understood.

### **3.2. Part 2: Identifying potential locations**

The second objective of the thesis intends to identify potential future locations that are likely to be suitable to providers for the placement of ARCFs in New Zealand. To establish the suitability for providers it is necessary to include providers in the decision-making process. It was intended that through the use of a survey, provider input into what makes a location suitable could be garnered.

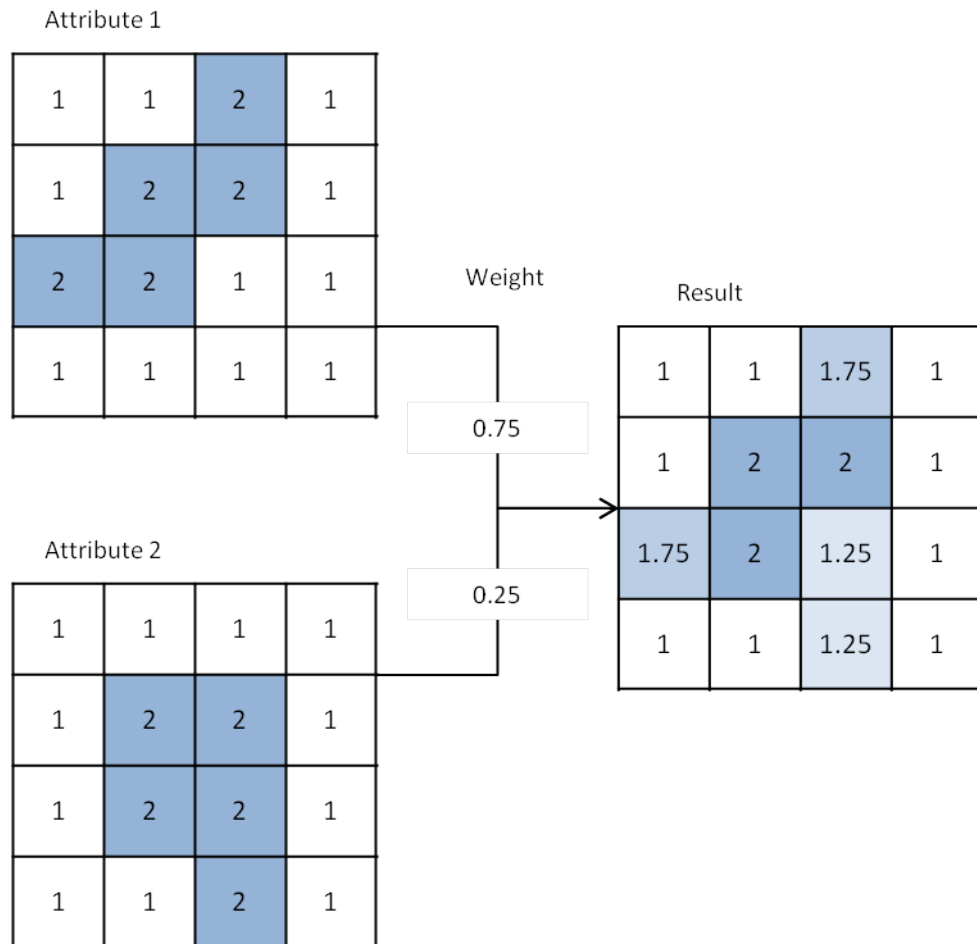
To identify the potential future locations, this thesis will employ a method from a larger pool of methods commonly referred to as suitability analyses. The general principal behind a suitability analysis is to identify smaller areas within larger areas that are more suitable (or less suitable) for a certain application. However there are many different ways of achieving this, the five primary of which are: gestalt analysis, ordinal combination, linear combination, weighted linear combination and non-linear combination (Hopkins, 1977). The most commonly used method for suitability analysis is weighted linear combination largely due to the ease with which it can be implemented within GIS (Malczewski, 2000). It was decided early on that weighted-linear combination would be the most appropriate for this exercise. For reasons of space, this discussion of methodological considerations will be limited to weighted-linear combination.

Weighted linear combination (WLC) is a spatial multi-attribute decision making technique based on the concept of a weighted average. WLC uses weighted averages to combine multiple spatial attributes together and calculate suitability scores for individual land parcels



(represented by cells or pixels). To do this the decision maker assigns weights of relative importance to each attribute (represented as a map layer in GIS) and calculates scaled values for each alternative on that attribute. Then the importance weights and alternative value are multiplied for each attribute and then summed by all attributes to yield a suitability map. A visual representation of WLC is presented below (Figure 3).

**Figure 3: WLC example**



Adapted from Malczewski (2000).

Presented as a formula WLC is represented as:

$$S = \sum w_i x_i$$

where  $S$  is suitability,  $w_i$  is weight of attribute  $i$ , and  $x_i$  is the alternative score of factor  $i$  (Drobne & Lisec, 2009). WLC can be performed using vector data (Drobne & Lisec, 2009), but it is generally recognised that raster is more appropriate for suitability applications (Malczewski, 2004).

Malczewski (2000) identifies six necessary steps in performing WLC when using GIS: (1) Identifying the set of attribute map layers, (2) defining the set of feasible alternatives, (3) generating commensurate attribute maps, (4) assigning attribute weights, (5) combining attribute weights and finally (6) map and ranking the grid cells. The following sections will explore the necessary methodological considerations using the procedure outlined by Malczewski (2000) when designing the suitability analysis using WLC for this exercise.

### **3.2.1. Identifying Attribute Map Layers**

The first step is the identification of attributes for the attribute map layers. Deciding on attributes that appropriately represent all the components that are necessary to meet the objective is a tricky business. In order for the attribute to be useful for spatial decision making, it must be comprehensive and measurable (Malczewski, 2000). To be comprehensive, an attribute's level must be able to indicate that the objective is achieved. To be measurable, the attribute must have a number value for each alternative and the values should reflect the decision maker's preference for each alternative.

Collectively, attributes must also possess properties in order to adequately represent a spatial decision problem and fulfil the objective. Keeney (1980) states that a set of attributes should be five things: [1] complete – so attributes should cover all aspects of the decision making problem; [2] operational – so they can be meaningfully used in the analysis; [3] decomposable – the performance of one alternative on one attribute is measured independently its performance on any other attribute; [4] non-redundant – not already covered by another attribute so as not to 'double count' its influence; and [5] minimal – so the number of attributes and the size is kept workable (Keeney, 1980). These principles however are often not addressed in WLC projects (Malczewski, 2000).

The process for the selection of attributes is therefore important. Common techniques include gathering the expert opinion (often via surveys) of decision makers or the use of previously identified attributes in the literature. Limitations with time and the need to survey provider decision-makers later on meant that survey was unfeasible. It was decided therefore that attributes selected by similar studies would be used. Two land-suitability analyses were identified in the literature review that sought to identify potential locations for ARCFs: In 2009, a detailed site selection process was undertaken on to select the location for a new State Veterans Home in Southwest Montana (SW Montana Veterans' Home Site Selection Committee, 2009) and a community identification study for a new veterans' home was undertaken for the Minnesota Department of Veterans Affairs in order to identify communities

within which to locate a new facility (Engan Associates & Ulteig, 2009). The attributes used from these analyses would serve as the attributes for the attribute map layers.

### 3.2.2. Defining the Set of Feasible Alternatives

Within each attribute map layer there will be one or more alternative. Feasible alternatives are identified by two means: either by exclusionary screening (also called boolean or logical constraints) or by a target constraints on the set of all alternatives (Drobne & Lisec, 2009; Malczewski, 2000). Exclusionary screening identifies alternatives as being either feasible or not feasible, and values the alternatives as either 0 or 1. The method of identification of identification might be “must be at least x distance from y” or “must be outside z”. Target constraints on the other hand might be something like “must be with within x distance of y”. Alternatives that meet the exclusionary constraints are given a value of one and included, while alternatives that don’t are given a value of 0 and excluded. The exclusion can take place within the analysis by modifying the WLC by multiplying the suitability by the value of the constraints:

$$S = \sum w_i x_i \cdot \prod c_j$$

where  $c_j$  is the criterion score of the constraint  $j$  (Drobne & Lisec, 2009).

As this thesis seeks to identify locations that are suitable to providers for the location of ARCFs, it is essential that providers have input on what constitutes a feasible alternative.

### 3.2.3. Generating Commensurate Attribute Maps

As attributes can be measured on any number of different scales, WLC requires that the values contained within the attribute map layers be transformed into comparable units (Malczewski, 2000). There are several different ways that this can be achieved.

Linear scale transformation is the most commonly used method of transforming input (or raw) data into commensurate attribute maps (Malczewski, 2000). There are a number of different linear scale transformation methods, the most commonly used of which is the *score range procedure*. In this procedure, the minimum attribute value is subtracted from all the attribute values and then rescales all the values by dividing them by the range (Malczewski, 2000). The result is a standardised attribute range from 0 to 1, where 1 is the most suitable attribute value and 0 the least suitable. The relationship is assumed to be linear. However, this linearity does not reflect what is often seen in spatial decision problems. When using proximity operations in spatial decision making, there is an implicit linearity assumed, but this is not often the case. Usually the “true” value function is curved and not straight.

An alternative to the linear transformation techniques is to use a value function approach. This approach converts different levels for an attribute into value scores using a value function (or curve). The idea is that the curve better approximates the true value function. One commonly used value function method is the midvalue (or value midpoint) method (Malczewski, 2000). In this method, like the linear method, the attribute score range is standardised so the minimum value is zero and the maximum value is one. Secondly, the decision maker estimates the value midpoint: where the incremental value of moving from the minimum value to midpoint is the same as the incremental value of moving from the maximum value to the midpoint (Keisler & Sundell, 1997). Then quarter values (0.25 and 0.75) are placed in the value midpoints between the minimum (0) and the midpoint (0.5), and between the midpoint (0.5) and the maximum (1). A curve can then be generated from these three points (Keisler & Sundell, 1997). The procedure can be repeated further to generate finer values. Once the value of the curve is defined, individual values can be defined by map algebra (Malczewski, 2000).

#### 3.2.4. Assigning weights to attribute map layers

Perhaps the most crucial component of the WLC process is assigning the weights to the attribute maps. Assigning weights to attribute maps allows the decision maker to model or quantify the relative importance of the attribute in the decision making process. There are many methods advocated in the literature for doing so, but few without considerable limitation. Incorrect calculation of weights is a common error in performing spatial decision making exercises using WLC (Lai & Hopkins, 1989; Malczewski, 2000).

One of the principal theorists in the field, Voogd (1983), identified five ways to determine weights for attributes (or *criterion priorities*) in public planning exercises:

1. Preference Analysis; where a decision maker or makers (experts) are questioned through means of interviews, questionnaires, or interactive procedures;
2. Behavioural Analysis: where the behaviour of people in similar situations is studied and revealed preference theory is used to determine quantitative values;
3. Direct System Description, where measurable characteristics of a criterion (attribute) are used to generate weights;
4. Indirect System Description, where the criteria (attributes) are subject to a multi-criteria evaluation and the scores become the weights for the criteria; or
5. Hypothetical Priorities, where criteria (attributes) are ranked by participants from the perspectives of various viewpoints (such as policy directions, scenarios etc.) (Voogd, 1983: pp.100-102)

As this seeks to incorporate the preferences of providers in choosing where to place and ARCF, preference analysis was identified as the most appropriate technique for this application. Further, as the development of new facilities is not a common process, performing a behavioural analysis on people deciding where to place facilities would likely require a substantially longer study period than this thesis allowed, and direct and indirect system description would both require expert knowledge from the researcher. Finally, while the first four allow the decision maker to develop quantitative weights, hypothetical priorities can only give quantitative statements making it not suitable for the development of numeric weights.

However, there are many different preference analysis methods for generating weights for attributes. From these, Drobne and Lisec (2009) identify four primary methods:

1. ranking methods
2. rating methods
3. trade off analysis methods
4. pairwise comparison methods.

Ranking methods are the most simple for assessing the importance of weights. Each attribute under consideration is ranked by the decision maker (or makers) in order of importance. If there are multiple decision makers the results are summed and the products converted to a zero to one range. This method has been used in many studies, but is often used in combination with a more advanced method (see Yahaya, Ahmad, & Abdalla, 2010; Yalcin & Akyurek, 2004). The principal limitation with ranking methods is that they give no attention to scale. For example a decision maker may view all the attributes as highly important, but is forced via the ranking method to rank them from high to low importance, and will be forced to apply the lowest possible ranking to the item chosen as lowest importance.

Rating methods refer to a collection of methods that use assigned ratings for each attribute by decision makers to develop attribute weights, the two principal of which are the grading method and the seven-point scale method. Grading methods use a grading system similar to that used in exams, where weights are given generated as a proportion of total suitability (see Kar & Hodgson, 2008). A total possible suitability value of 100 is divided between the attributes so that each is worth a proportion of the total. This proportion is then divided by 100 and becomes the weighting. If there are more than one decision maker, the average of these weights becomes the final weighting for each attribute. As the number of attributes rises, the coarseness of this operation increases. Unless the units change, as the number of attributes rise, the ability to make finer value judgements between attributes disappears. It also requires the decision maker to balance the attributes against one and other, similar to the

pairwise technique. However, it forces the decision maker to make the pairwise type judgements in a single step. While this may be fine for studies with fewer attributes, it would be hard for studies with more attributes.

The seven-point scale was first advocated by Osgood, Suci, & Tannenbaum (1957). They argued that seven categories is sufficient to allow people to express their preferences adequately. The scale uses what they deemed the 'semantic differential' to give the scale meaning for decision makers; at one end of the scale is a label with an expression, and the other end of the scale has an opposite expression (see Figure 4: Seven-point scale). The decision makers are asked to designate for each attribute a number or value along the scale. This means that the weights are in the same scale (between 1 and 7). These values can then be standardised to create weightings for each attributes. If there are multiple decision makers, the mean value can be used (Voogd, 1983).

Figure 4: Seven-point scale example

Unimportant   1   2   3   4   5   6   7   Important

(Voogd, 1983; p.104)

There are two main advantages of using a seven point scale: Firstly, multiple attributes can be evaluated individually with a minimum of questions which is useful when there is a large number of attributes. And secondly, all the attribute weights are calculated on the same scale, meaning there is some homogeny between them (FERENCE, 1996).

Malczewski (2000) argues that trade-off analysis (or swing weights technique) is the most optimal method when using WLC. This method involves asking a decision maker to compare a change from the least-preferred to the most-preferred on one attribute to a similar change in another attribute (Malczewski, 2000). He/she is then asked to visualise a hypothetical grid-cell with each attribute at its least preferred level. They are asked if just one of the attributes could be changed to its best level, which they would choose. They are then asked which would be their next option until all the attributes are ranked.

Next, the highest ranked attribute is assigned a weight of 100. The decision maker is then asked to compare a swing from the least preferred value to the most preferred value on the second ranked attribute to a swing from the least preferred value to the most preferred value on the first ranked attribute and assign a percentage value to indicate the importance. For example, if the decision maker thinks the second ranked value is 60% as important as the highest ranked value, a weight of 60 is applied. This is then repeated for the third ranked

attribute compared again to the highest ranked attribute. For the sake of the example, let's assume this value is given as 20. The weights are then normalised with the as follows:

$$w_1 = \frac{100}{100 + 60 + 20} = 0.556$$

$$w_2 = \frac{60}{100 + 60 + 20} = 0.333$$

$$w_3 = \frac{20}{100 + 60 + 20} = 0.111$$

Adapted from Malczewski (2000)

While this method has been used in spatial decision making exercises using WLC (see Keisler & Sundell, 1997) its use is comparatively rare. The analysis relies on the decision maker(s) having full knowledge of the range of values for each attribute values prior to performing the comparison. Further, for it to function properly, a study should be run to determine the range and values for each attribute, and these be presented to the decision maker as they are making the decision.

Other authors suggest that pairwise comparison is the most optimal method for use with WLC (Drobne & Lisec, 2009). Pairwise comparison was developed by Saaty (1977) as a part of a decision making process known as the analytical hierarchy process (AHP). Since then it has been commonly used in conjunction with WLC and GIS. The method requires that attributes are compared against each other using a nine-point continuous scale (Figure 5).

Figure 5: Pairwise comparison scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two objectives contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Immediate values between the two adjacent judgments	When compromise is needed

(Saaty, 1977)

The decision maker compares the relative importance of each attribute to every other attribute in turn. This is then repeated for the next attribute until all attributes have been compared to all other attributes. The results are collated into a pairwise comparison matrix. The relative importance weights are then generated from the eigenvector of the pairwise comparison matrix (Drobne & Lisec, 2009).

The biggest limitation of the pairwise comparison technique is the number of questions required. For  $n$  attributes, there are  $n(n - 1)/2$  questions necessary (FERENCE, 1996). Malczewski (2000) also questions the meaningfulness of the resultant weight to the underlying question, as they effectively ask for the relative importance of attributes without reference to the scale or units of measurement. Choosing the most appropriate method is important the success of this exercise (Malczewski, 2000). The advantages and disadvantages of each method are summarised below (Table 2).

**Table 2: Advantages and disadvantages of each method of assigning weights to attribute maps**

Method	Advantages	Disadvantages
Ranking methods	<ul style="list-style-type: none"> <li>• Simple to use</li> <li>• Very few questions</li> </ul>	<ul style="list-style-type: none"> <li>• Limited history of application as a standalone method</li> <li>• Does not consider scale</li> <li>• Less mathematically sound</li> </ul>
Grading method	<ul style="list-style-type: none"> <li>• Simple to use</li> <li>• Very few questions</li> </ul>	<ul style="list-style-type: none"> <li>• Is problematic to use with more than ten attributes</li> <li>• Less mathematically sound</li> </ul>
Seven-point scale	<ul style="list-style-type: none"> <li>• Simple to use</li> <li>• Very few questions</li> </ul>	<ul style="list-style-type: none"> <li>• Less mathematically sound</li> </ul>
Trade-off method	<ul style="list-style-type: none"> <li>• Mathematically robust</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a large number of questions</li> <li>• Relies on decision makers having full knowledge of attribute values beforehand</li> </ul>
Pairwise comparison	<ul style="list-style-type: none"> <li>• Mathematically robust</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a large number of questions</li> <li>• Relies on decision makers having full knowledge of attribute values beforehand</li> </ul>

The most desirable methods to use are the trade-off method and pairwise comparison. However the relatively large number of attributes collected by the literature review would require that a much higher number of questions would need to be asked of survey respondents than is practical. The same high number further excludes the grading method. For these reasons a seven-point scale was seen as the best compromise between quality of response, and acceptability of survey length for respondents.



### 3.2.5. Combining attribute maps and weights and ranking the alternatives

The final two steps are combining the attributes and the weights and ranking the alternatives. As explained in section 3.2, factors are combined by applying a weight to each, followed by a summation of the results to yield a suitability map:

$$S = \sum w_i x_i$$

where  $S$  is suitability,  $w_i$  is weight of factor  $i$ , and  $x_i$  is the alternative score of factor  $i$  (Drobne & Lisec, 2009). Once the results are combined into a single suitability map, the results can be ranked, and the locations that best fit the suitability criteria selected. One limitation of WLC is what Malczewski (2000) calls the assumed *linearity* and *additivity* of the attributes, whereby it is assumed that the desirability of an additional unit is consistent for any level of that attribute and that the preference for one attribute is independent of the value of another.

### 3.3. Part 3: Choosing optimal locations

The third objective of this thesis is to select from a series of candidate locations using GIS, the most optimal locations for ARCFs given the distribution of the population. Processes for selecting optimal locations in GIS are known as location analyses and encompass a wide range of methods for positioning facilities in a given space (ReVelle & Eiselt, 2005). The most sophisticated of these methods is location-allocation analysis.

Location-allocation analysis is a network-based method for selecting the optimal sites for facility location given a set criterion or criteria. The method involves simultaneously selecting a set of locations for facilities and assigning spatially distributed demand centres to these facilities to optimise a measurable criterion (Rahman & Smith, 2000). The principal methodological concern for the location-allocation analysis is the selection of the appropriate method for the application. There are many variations on the location-allocation method for different location-allocation problems (Zhou & Liu, 2003).

These problem types occupy two primary categories: single-level location-allocation methods (SLAMs) and hierarchical location-allocation methods (HLAMs). SLAMs are the most common method of location-allocation due to their relative simplicity and applicability to a wide range of applications. They are used in situations where the facilities are assumed to offer the same level of service (Rahman & Smith, 2000). For example in the health sector, a SLAM might be used to locate a new full-service hospital. As full-service hospitals are the highest level in the hierarchy of health facilities it can be assumed that only hospitals provide that level of service. HLAMs on the other hand are commonly used where there are many levels of service provided by different facilities (ReVelle & Eiselt, 2005). For example a health system will likely contain a

hierarchy of services i.e. from nursing outreach posts at the lowest level to mid-level clinics at the next level to hospitals at a higher level. Each of these facilities might supply all the services of the facilities below, plus additional services. A HLAM might allow the researcher to calculate how to serve as many people as possible within feasibility (e.g. cost) constraints (ReVelle & Eiselt, 2005).

This thesis makes the assumption that all ARCFs provide the same level of service. As will be explained in the data chapter, the lack of disaggregated data by bed type means that this thesis cannot differentiate between aged residential service types. It also assumes that only ARCFs will provide the aged residential care services. For these reasons single-level location-allocation models are the most appropriate for this exercise. There are however many different SLAMs, and choosing the appropriate method for the application is of considerable importance. A list of the most common SLAMs is provided below (Table 3).

**Table 3: Single-level location-allocation methods**

Location-allocation problem types	Description
P-median problem	Locates a number of facilities ( $p$ or fewer) so that total weighted travel distance/time between facilities and demand centres is minimised
Location set covering problem (LSCP)	Returns the minimum number of facilities and their locations so that every demand centre is served by at least one facility
Maximal covering location problem (MCLP)	Returns the locations for a fixed number of facilities so that the most demand centres are served within a given service time/distance
Capacitated maximal covering location problem (CMCLP)	A variation on MCLP with a capitation limit at facilities

The P-Median method is the simplest and probably the most commonly location-allocation method. The method locates a number of facilities ( $p$  or fewer) so that total weighted travel distance/time between facilities and demand centres is minimised. The analysis assumes that the smaller the total weighted travel time from demand centres to allocated facilities, the more accessible the facilities are. The main limitation of this model however is that it does not account for the ‘worst case’ situations where the facility allocated to a demand point is not suitable from a service point of view (Rahman & Smith, 2000). As minimised total weighted travel distance/time is the target, a small number of facilities may be allocated to facilities a large distance away.

Location set covering problems (LSCPs) methods emerged as a solution to this problem (Rahman & Smith, 2000). An LSCP returns the minimum number of facilities and their locations

so that every demand centre is served by at least one facility (ReVelle, Toregas, & Falkson, 1976). However, in many applications there are simply not the resources to locate enough facilities to serve every demand centre. This is a common problem in the public health system where finite public resources need to be allocated efficiently to maximise public health benefit.

The maximal covering location problem (MCLP) developed by Church and ReVelle (1974) seeks to address the problem of finite resources by locating a fixed number of facilities so that the most demand centres are served within a given service time/distance. The principal limitation with MCLP however, which also applies to the previous methods is that it does not account for the limited capacity at facilities (Rahman & Smith, 2000). For example a facility might be located by the analysis to the centre of a city to most effectively serve the surrounding population. However the capacity of the facility might not be sufficient to meet the allocated demand.

A variation on MCLP that begins to address this is the capacitated maximal covering location problem (CMCLP). As the name suggests CMCLP allows the researcher to specify a maximum capacity for each facility above which level demand can no longer be allocated to that facility (Current & Storbeck, 1988). Similar capacity constraints have also been applied to p-median problems (see Jacobs, Silan, & Clemson, 1996) and LSCPs (see Cornuejols, Sridharan, & Thizy, 1991).

### **3.3.1.        Weighing up the alternatives**

The intention for these methods is to identify the most optimal locations for ARCFs given the distribution of the population. Therefore, any location-allocation problem types used need to be suitable for application to the aged residential care sector in New Zealand. The advantages and disadvantages of each method are summarised below (Table 4).

**Table 4: Advantages and disadvantages of each single-level location-allocation method**

Problem type	Advantages	Disadvantages
P-median problem	<ul style="list-style-type: none"> <li>• Commonly used</li> <li>• Allocates a set number of facilities</li> </ul>	<ul style="list-style-type: none"> <li>• As minimised total weighted travel distance/time is the target, remote demand points may be allocated to facilities a large distance away</li> <li>• Does not account for capacity constraints</li> </ul>
Location set covering problem (LSCP)	<ul style="list-style-type: none"> <li>• Ensures every demand point is served by at least one facility within a given time</li> </ul>	<ul style="list-style-type: none"> <li>• No restriction on the number of facilities located - does not account for finite resources</li> <li>• Does not account for capacity constraints</li> </ul>
Maximal covering location problem (MCLP)	<ul style="list-style-type: none"> <li>• Locates a fixed number of facilities so that the most demand centres are served within a given service time/distance</li> </ul>	<ul style="list-style-type: none"> <li>• Does not account for capacity constraints</li> <li>• Demand points outside maximum service time may not get allocated to facility</li> </ul>
Capacitated maximal covering location problem (CMCLP)	<ul style="list-style-type: none"> <li>• Locates a fixed number of facilities so that the most demand centres are served within a given service time/distance</li> <li>• Accounts for capacity constraints</li> </ul>	<ul style="list-style-type: none"> <li>• Demand points outside maximum service time may not get allocated to facility</li> </ul>

As the literature review found no previous applications of location-allocation problems to ARCFs nationally or in New Zealand, the decision on problem type was largely dictated by the context and not previous applications. The principal concerns were that the facilities must meet a minimum operating efficiency of 80-beds, and that every demand point must be allocated to a facility. It was decided that to properly account for restrictions on the minimum number of beds a facility requires to meet minimum operating efficiencies a capacitated method would need to be used. The ESRI software package being used for this analysis contained only a one in-built capacitated location-allocation problem method: a capacitated maximal covering location problem (CMCLP) model called 'maximize capacitated coverage'. This was chosen as the most suitable method for the context.

### 3.4. Summary

This chapter investigated the common methods used in similar applications to each of the three objectives of this thesis. It then compared and evaluated them for suitability to this context of this study.

In part one, the methodology identified two primary categories of GIS-based methods for measuring spatial access to health services including applications with ARCFs: area-based measures, which describe for pre-defined areas the ratio of population need to services available, and impedance-based measures, which describe the impedance between the population and health care services. Within these two categories, several principal methods were identified and the advantages and disadvantages of each method were summarised in Table 1. A combination of bed-to-population ratios and travel impedance to nearest provider were identified as the most acceptable to this application.

In part two, the methodology identified WLC as the most commonly used method and the most appropriate for this study. Subsequently, to achieve the objective three key steps were performed: a review of the literature to identify spatial attributes important to decision-makers when locating new facilities, a survey of providers on the relative importance they assign to each of the attributes when deciding where to locate ARCFs, and a suitability analysis using WLC to aggregate the spatial attributes together by their relative importance to identify areas of potential suitability.

In part three, the methodology chapter identified location analyses as the category of GIS methods that might be used to for positioning facilities in a given space (ReVelle & Eiselt, 2005). Location-allocation analyses were further identified as the subcategory of location analyses most likely to be suitable for this study. Different location-allocation methods (problem types) were then compared and capacitated maximal covering location problem (CMCLP) identified as the most suitable for this study.



## 4. Methods

This chapter describes the methods used in this thesis. The chapter is split into three parts, one for each of the three thesis objectives. Part one describes the process by which the current spatial accessibility of ARCFs was measured to establish whether there was indeed a need for intervention and provide a baseline for comparison. Part two describes the suitability analysis methods by which locations that were potentially appropriate for the placement of ARCFs were identified using expert opinion and GIS mapping techniques. Part three describes the location-allocation method used to choose from the potentially suitable locations for ARCFs those location which would best supply the projected demand, and maximise the spatial accessibility.

### 4.1. Part 1: Measuring current spatial accessibility

The first objective of the thesis is to describe and measure the current accessibility of ARCFs to establish the need for intervention and get a baseline for comparison. To achieve this objective, two separate measures of spatial accessibility were used: Bed-to-population ratios and travel time to nearest facility.

#### 4.1.1. Bed-to-population ratios

Bed-to-population ratios are as the name suggests, a ratio of beds to population within a defined geographical area. As described in the methodology section, travel time to provider is a measure of availability of a service but not accessibility, and provide good comparison between larger areas (Guagliardo, 2004).

As will be explained in more detail in the data chapter (section 5) population weighted area unit centroids were generated from population data by administrative unit from the Statistics New Zealand website, and point location of ARCFs from the MOH. These point locations were then joined in ArcGIS Desktop 10.1 (Redlands, CA: Environmental Systems Research Institute) with DHB polygons, urban/rural category polygons and New Zealand Deprivation Index (NZDep06) polygons to allow ratios to be calculated by each of these three categories. The resulting data were then exported as comma-separated variable (CSV) files for analysis in Excel.

Bed-to-population ratios were then calculated by DHB, urban/rural category and New Zealand Deprivation Deciles (NZDep06) using the following formula :

$$A_i = \frac{y_i}{x_i} \times 1000$$

where  $A_i$  is the bed-to-population ratio for the region  $i$ , and  $y$  is the number of beds in the region and  $x$  is the population.

#### 4.1.2. Travel time to nearest facility

Travel time to nearest facility measures the cost of travelling from an incident (in this case a population point) to the nearest facility along a network. As described in the methodology section, travel time to provider is a measure of accessibility but not availability. The value of this method is that both the concept of the model and the resultant data is more intuitive and easily understood by decision makers (Brabyn & Skelly, 2001).

Population weighted area unit centroids were used to represent the population points (incidents). As explained in more detail in the data section, area units were used as population projections are not available at a meshblock level. Therefore, for continuity between the current spatial accessibility measures and the projected measures, populations were aggregated to area units and the centroid of the area unit was taken as the population point. The 'mean centre' tool in ArcGIS would give the exact middle point of each area unit, but this point was not necessarily representative of the location of the populations within the area unit. In some larger area units however, the population sometime tended to be concentrated in one part and the rest of the area was largely unpopulated. To limit the negative effects of this aggregation, the centroid of the area unit was weighted by the distribution of the meshblock centroids within it. The distribution of these centroids acts as a proxy for population distribution. The mean centre was then found for all the meshblock centroids within each area unit, and this point was used as the population weighted centroid for the area unit. ARCF point data as provided by the MOH were used as the facility inputs.

The network analysis capabilities of ArcGIS were used to calculate the cost to the nearest facility. The closest facility analysis tool is designed specifically for this task and uses a multiple-origin, multiple-destination algorithm based on the shortest path algorithm developed by Dijkstra (1959) (commonly known as Dijkstra's algorithm). The tool allows the user to specify the direction of travel (to or from a facility) and the number of facilities to find, and returns the best routes between incidents and facilities, and reports their travel costs (ESRI, 2012).

The incident and facility data points were loaded into the model and the analysis was run first for the North and then for the South Island, and then run again individually for each DHB. Resultant costs were displayed as travel time (minutes). The route data from the resultant layers were then exported as CSV files for analysis in Excel.



## **4.2. Part 2: Identifying potential locations**

The second objective of this thesis is to identify potential locations that would be suitable to providers for the location of ARCFs in the future. To achieve this, a suitability analysis using a combination of survey methods and WLC was performed.

### **4.2.1. Identifying potential spatial attributes**

The literature review found little information on the spatial factors that influence where providers choose to place ARCFs. Due to time constraints it was not feasible to survey providers for spatial factors that influence their decision making, compile them and then survey them again to gain the relative importance for the WLC analysis. It was decided that a combined list of all the appropriate spatial attributes used in similar exercises would be used. Two studies were deemed suitably similar, both site-selection processes for State Veterans Homes in the United States. In both studies, from Montana (SW Montana Veterans' Home Site Selection Committee, 2009) and Minnesota (Engan Associates & Ulteig, 2009), the site-selection criteria used were detailed.

In Montana, a site selection committee was established to evaluate potential sites and decide on a final location for new State Veterans Home (SW Montana Veterans' Home Site Selection Committee, 2009). The committee developed a list of selection criteria and weightings by which to assess suitability of potential sites. Their site-selection process can be observed from a series of meeting minutes and associated documents published online (Montana State Government, 2011; SW Montana Veterans' Home Site Selection Committee, 2009). A similar procedure was undertaken in Minnesota in 2009 where Engan Associates and Ulteig conducted a community identification study for a new veterans' home on behalf of the Minnesota Department of Veterans Affairs in order to identify communities within the State where it would be most feasible to locate a new facility (Engan Associates & Ulteig, 2009).

The spatial attributes from both examples were collated and examined for relevance to the context of this project. Several criteria relate to the potential demand for the services in the region. As the final section of our thesis will choose between locations based on demand, these spatial attributes were excluded. Where classes of a single criterion were displayed as separate spatial attributes in the original documents (for example site access in Montana was split across three attributes: Paved roads with curbs and sidewalks; Paved roads with curbs; Paved roads with county road profile), they were amalgamated into a single attribute. The full list of the considered spatial attributes can be observed in Appendix one.

The spatial attributes were then assessed for data availability. No data was found on national distribution of health workforce (registered nurses, social workers and physical therapists) so a

decision was made not to use proximity to these as a spatial attribute. Access to construction contractors and mortuary services was similarly excluded due to no national data being available. Access to public transport was also paired back as there was no available public transportation shapefile or network datasets available for New Zealand at a national level. While not optimal, it was decided that access to taxi or shuttle services would have to suffice, and access via the road network would be appropriate. Finally, proximity to fire hydrants was not used due to lack of complete data on hydrant location.

Fifteen spatial attributes were identified as being attainable and suitable to the New Zealand (Table 5). These attributes were then grouped into five classes: Emergency response, associated health services, utilities, zoning, and public transport.

**Table 5: Selected spatial attributes by topic**

Topic	Spatial attributes
Emergency response	Travel time to a 24-hour emergency department
	Response time from a fire station
Associated health services	Travel time to a public hospital
	Travel time to a GP
	Travel time to a dentist
	Travel time to a psychologist
	Travel time to a psychiatrist
Utilities	Distance to a water supply network
	Distance to a sewerage pipeline
	Distance to a natural gas pipeline
	Distance to a telephone line
	Distance to a electricity distribution line
	Distance to an access road
Zoning	That the region has appropriate zoning
Transportation	Travel time to a taxi or shuttle depot

#### 4.2.2. Survey design

Next, as this thesis was seeking to determine the suitability for providers, the importance of each attribute for providers had to be established. A survey to determine relative importance weights and attribute values for each of the fifteen spatial attributes was created. Providers who had built a new facility in the previous two years were chosen as suitable candidates. With the respondents being potentially nationally distributed and with likely initial contact occurring via email, an online questionnaire method was chosen. Qualtrics online data collection software ([www.qualtrics.com](http://www.qualtrics.com)) was chosen as the survey software.

It was assumed that respondents would be busy professionals in the aged residential care industry, whom would likely be time-poor. Therefore, a maximum survey completion time of 15 minutes was targeted. This target length influenced the design of the questionnaire. It was

also assumed that there may be concerns from respondents about themselves or their company being identified from their responses. The survey was made anonymous to avoid identification and potentially increase the response rate.

Fitting with an anonymous survey, demographic questions were kept broad and optional. Respondents were asked to report whether their organisation was for profit or not-for-profit, and how many ARCFs they operated. The survey was approved by the School of Geography, Environment and Earth Sciences Ethics Officer. Consent was requested by asking the respondents to check “I Agree” after the information section at the start of the survey. Information sheets were also emailed with the invitation to participate. A separate information sheet was also emailed to respondents, along with the link to the survey. The full survey can be found in Appendix two. Two primary types of data were targeted with the survey: [1] the relative importance of each spatial attribute, and [2] which alternatives within the attribute were more or less desirable.

#### *4.2.2.1. Eliciting attribute weights*

Initially it was hoped that the pairwise comparison method would be able to be used to determine the relative importance of each spatial attribute. As discussed in the methodology (section 3.2.4), for  $n$  attributes, there are  $n(n - 1)/2$  questions necessary to perform a pairwise comparison (Ferrece, 1996). For the 15 attribute map layers in this study, 105 questions would need to be asked to calculate the size of the weights alone.

With the high amount of time required for a respondent to answer 105 questions, the small pool of possible respondents, and the need for a high percentage of those to agree to participate, a seven point scale rating method was chosen. This method allows just a single question to be asked for each attribute to obtain a relative importance value. For each spatial attribute the question was posed “How important is [insert spatial attribute] when deciding where to place an aged residential care facility?” The respondent could then choose to place a slider bar along a seven-point scale, where a value of one was ‘relatively unimportant’ and a value of seven was ‘very important’. To ensure responses, the answering of these questions was made compulsory before the respondent could move on to the next question.

Figure 6: Example survey question

### 24-Hour Emergency Department (ED)

How important is travel time to the nearest 24-hour emergency department when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

	Relatively unimportant			Very important			
	1	2	3	4	5	6	7
Travel time to nearest 24-hour emergency department							

What would be the maximum travel time from a 24-hour emergency department that you would feel comfortable with when

#### 4.2.2.2. *Eliciting attribute values*

The next goal was to elicit attribute values for each of the spatial attribute layers. The challenge was to achieve this within a small number of questions to maintain the fifteen minute target.

Respondents were asked to give the maximum travel time from the spatial attributes that they would feel comfortable placing an ARCF. The idea behind this was to compile a list of travel time thresholds for each spatial attribute from the spatial attribute locations, and generate attributes for the layer from travel-time from these. The values of the attributes could then be generated from the number of respondents comfortable with that travel time threshold.

For example, in answer to the question “What is the maximum travel time from a  $x$  that you would feel comfortable placing a facility” there might be four identified threshold times across seven participants. Three respondents could have said they would be comfortable with a maximum travel time threshold of 15 minutes, one respondent said they would be comfortable with a maximum travel time of 20 minutes, two respondents said that they would be happy with a travel time of 30 minutes, and the final respondent said that they would be happy with a maximum travel time of 60 minutes. From this we would generate the following table (Table 6).

**Table 6: Example table travel time thresholds**

Time threshold (minutes)	Number of respondents who specified the time threshold as their acceptable maximum	Number of respondents happy with that travel time	Percentage of respondents happy with the travel time	Attribute value
15	3	7	100	1
20	1	4	57	0.57
30	2	3	43	0.43
60	1	1	14	0.14

For each travel time threshold, we can generate a count of the number of respondents who specified that travel time as the maximum that they were happy with. For the smallest travel time threshold, we know if the spatial attribute in question is within this threshold then it would be acceptable for all respondents. For the next smallest, it would be acceptable for all the respondents accept those that specified the smallest as being the maximum. Therefore, by subtracting the 'count' value from the previous row from the total number of respondents, we can have the total number of respondents who would be happy with that travel time. For successive rows, the count values from all previous rows need to be subtracted. We can then calculate the percentage of respondents who would be happy with the each threshold. By dividing the percentage by 100 we can generate an attribute value for that threshold for the next stage of the analysis. To reduce the number of questions, respondents were not asked to put a maximum distance from utilities. It was assumed that access thresholds could be reasonably estimated from the data provided.

There were two further optional sets of questions at the end of the survey. Respondents were also asked to suggest alternative spatial attributes and then give them a score on the seven point scale, with the option to suggest up to a maximum of ten spatial attributes. Respondents were also asked for any other comments they had regarding the survey. Respondents that wished to receive a summary of the findings had the option to leave there email address by clicking a link to a separate survey form. The email address was not linked to their other responses.

#### **4.2.3. Recruitment**

The New Zealand Aged Care Association provided a list of eleven organisations that had built new facilities or had undertaken major expansion in 2010/2011. Initial contact involved a personalised email to the CEOs or General Managers of each of these organisations explaining the context and asking for assistance in the research. Responsive individuals were then sent a

full information sheet with the link to the online survey and asked to distribute the sheet to relevant people within their organisation.

Initial contact was made with the chosen organisations via email. The preliminary response was relatively positive, with four organisations (of 11) agreeing to take part. In an effort to recruit more organisations, follow-up emails were sent with an imbedded link to the survey with a request to distribute to relevant people within the organisation. Six (of 11) organisations in total contacted me expressing a willingness to participate. One organisation declined to participate as they only performed renovations on an existing site and had not chosen a new site. The remaining four organisations had links to the survey but I received no indication as to whether anyone was going to take part. The survey links were distributed from mid-2012 and the survey was taken offline in January 2013.

Out of ten possible organisations there were eight responses. One respondent had given a value of “1” for every answer, including for maximum response times, obviously in intent to view all the questions before answering. This response was removed from the analysis. The remaining seven responses became the study group. The responses from these seven individuals were exported from Qualtrics as a Microsoft Excel file for analysis.

#### **4.2.4. Generating attribute maps**

Once the survey had closed, attribute maps for each spatial attribute were created. Survey result tables were created for each spatial attribute (such as in Table 6). From these, spatial attribute attribute maps were generated.

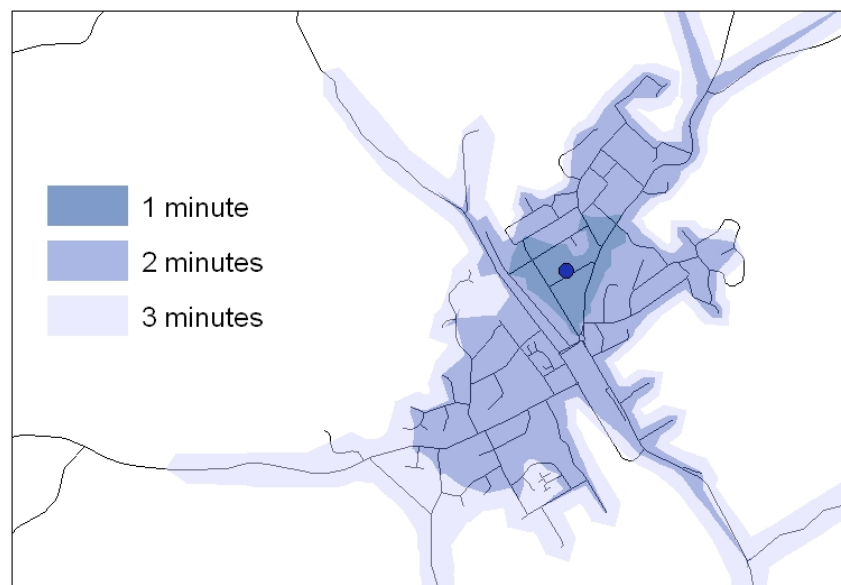
The spatial attributes were split into two batches: travel-time spatial attributes, and access spatial attributes. Travel time spatial attributes were those where the attribute data was generated using the reported maximum travel time thresholds from an item of interest. The emergency response, associated health services, and public transportation spatial attributes all fell under this classification. Access spatial attributes were those where attribute data was not requested as the data was assumed to be yes/no (i.e. yes there was access/no there was not access). All the utilities spatial attributes were access type spatial attributes, as was the zoning attribute.

The location data for each spatial attributes were collected. The full data collection process is explained in the data chapter (section 5.6). As per the spatial accessibility measures in Part 1, the data was split into North Island and South Island, so as to be able to run separately, and improve computational time. From this data, travel time thresholds were generated to form the attribute data for the spatial attribute map. Again the network analysis capabilities of

ArcGIS were used, specifically the service area tool. The service area tool generates regions (polygons) that encompasses all streets that are within a specified impedance (in this case time) from an item of interest.

For each travel time attribute a service area analysis generated using the point data for the locations of interest as the facility inputs, and the travel time thresholds as default break values. The analysis was also set to generate simplified polygons, merged by value, and outputted as 'rings'. These service area analyses were then solved, and the resultant polygon data for each was saved in a new feature class (see Figure 7).

**Figure 7: Example travel time thresholds**



To create the final spatial attribute maps for the travel time spatial attributes in preparation for the WLC, the travel time attribute feature classes were then converted from vector into raster. Firstly to ensure all the raster layers could be overlaid perfectly, two 1,600km<sup>2</sup> vector squares were generated to contain the North and South islands. These were then converted to raster, with a cell size of 100mx100m. Each of the travel time attribute feature classes were then converted to raster, using the same 100mx100m cell size and the newly generated reference squares as 'snap rasters'. The threshold values were then reclassified to the count of respondents happy with that threshold. Everywhere outside the largest threshold was given a value of zero.

Thresholds were then generated around the utility spatial attributes. With the exception of the access road attribute, it was assumed that a threshold distance of 2km was appropriate. For the access road attribute it was assumed that 1km was an appropriate maximum distance. These were then converted to raster following the same process as the travel time spatial

attributes. Areas within the threshold were then reclassified as 7, and areas outside were then reclassified as 0.

#### 4.2.5. Generating spatial attribute weights

To calculate the spatial attribute weights, the results for each "How important is [insert spatial attribute] when deciding where to place an aged residential care facility?" question, were averaged for each spatial attribute. All the average scores were then transformed into the same 0-1 scale.

#### 4.2.6. Weighted linear combination (WLC)

Once the spatial attribute maps were complete, and the weighting generated, the results were compiled with a WLC analysis. The spatial attribute maps were each multiplied by their respective weightings and summed together to form a single attribute map in raster calculator. The formula used is as follows:

$$WLC = (\text{Spatial attribute map 1} \times \text{Spatial attribute weighting 1}) \\ + (\text{Spatial attribute map 2} \times \text{Spatial attribute weighting 2}) + \dots$$

The resultant map was a floating point raster. Values ranged from 0, where none of the respondents identified that area as being suitable for any of the spatial attributes, to 7, where all the respondent agreed that this area was suitable for all of the spatial attributes. This was converted in to integer. A value of 0 was returned as 0. Values between 0 and 1 were returned as 1. Values between 1 and 2 were returned as 2. This continued up to a value of 7. The raster was then converted into a polygon feature class with separate polygons for each of the eight grid values (0-7).

The next step involved identifying which above which value score would be reasonable to place an ARCF. Areas which scored zero were naturally excluded automatically as they were clearly not suitable. A cut off value of seven was decided to be unrealistic, as the only areas which scored a perfect 7 were main urban centres. It was assumed that there would always be a measure of compromise in choosing an ARCF and as such the value would likely be less than seven. So instead a 'minimum acceptability value' was identified above and including which areas would be assumed to be acceptable. To calculate this value the location of existing ARCFs was overlaid upon the surface and used as a proxy for acceptable compromise. It was assumed that if 95% of existing facilities corresponded with a value, that value could be assumed to be suitable. WLC score was converted to an integer and the proportion of facilities by WLC value exported. The resultant point feature class returns the location of the ARCFs with the WLC value associated with that location.



The last stage was to convert the acceptable areas into a point feature class so that the locations could be used in Part 3. The intention for this step was to identify regions that contained a possible selection site or sites. Meshblocks, being the finest form of census unit in New Zealand, were chosen to define the regions. Areas that were of a suitable size for the locating an ARCF had to be identified. To determine an adequate size for a facility, the Grant Thornton review's Greenfield model scenario was used. The review identified an appropriate facility size of 45m<sup>2</sup> per resident, and a recommended facility size of 80 beds, and a site coverage of 35%, equating to an ideal facility land size of 10,286m<sup>2</sup>. The suitable area polygons were then split by meshblock, and the areas of each polygon were generated. Suitable areas that were smaller than the required ideal were discarded. Meshblocks that contained areas of a suitable size were then selected and imported to a new feature class. The centroids of these meshblocks were then generated, and exported as a point feature class.

### **4.3. Part 3: Choosing optimal locations**

The third objective of the thesis was to determine where the new facilities should go so that spatial accessibility is maximised. To achieve this, the location-allocation functionality in ArcGIS 10.1 was utilised. As described in the literature review (section 2.1), two separate scenarios were generated by the Grant Thornton (2010) review: Scenario A (52,291 beds required in 2026) and Scenario B (44,129 beds required in 2026). A location-allocation analysis was performed for both models. As the facilities had a capacity to which they had to adhere, the 'maximize capacitated coverage' model was used to solve for a capacitated maximal covering location problem (CMCLP).

A pilot test of the data revealed that computer processing constraints meant that location-allocation analysis could not be run for the entire North Island in a single operation. For that reason the analysis was split in twenty separate analyses: one for each of the DHBs in New Zealand. DHBs were chosen as they represented the likely first level aggregation that would be used if this method were to be applied nationally.

#### **4.3.1. Setting up**

Firstly, the demand points needed to be established. An excel spread sheet containing population projections for 2026 by area unit was joined to the North and South Island area unit population weighted centroid feature class. Projected population of each area unit within our study area (mainland North and South Islands) was summed and then divided by the total number of beds estimated for 2026 in scenario A. This produced a bed-to-population rate. A new integer field was added to the feature class. Using the field calculator tool, the population size for each area unit was then divided by this value giving a demand value for each area unit.

By virtue of using an integer field, the resultant value is rounded to the nearest whole number, as the analysis requires integer values.

$$\text{Area Unit Demand} = \text{Area Unit population} / \left( \frac{\text{Total population}}{\text{Total beds}} \right)$$

The process was then repeated for scenario B.

A central flaw in the location-allocation tool in ArcGIS 10.1 is that the demand weight for each demand point can only be located to a single facility, regardless of this size of the demand. That causes issue when you have a capacitated facility size: i.e. when there may be enough space to allocate the demand if split between a few facilities, but not enough space at any facility to accept the whole demand weight. An obvious solution to this might be to create a demand point for each individual unit of demand. However this would severely impede computing time. A pilot test indicated that that method would be too computationally intensive for the machine used.

A simpler, but less ideal method was to replicate the demand points  $x$  times, and then multiply the capacity of the facilities by  $x$ . This means that the demand weight at each demand point could be located to up to  $x$  different facilities. Pilot tests with the data found the computational limit of  $x$  for the computer being used to be slightly above  $x = 20$ . Therefore 20 was used as the multiplier value.

The next step was to generate a feature classes of pre-existing facilities to serve as the required facilities. The Grant Thornton (2010) review warns that many facilities will not have the capacity to expand to the minimum efficient operating size of 80 beds. As no data was available as to which facilities would likely not be able to adapt, it was assumed that beds that facilities currently 65 beds or larger would have the capacity to expand, and those less than 65 would not. Using the select by attributes tool, facilities with total beds 65 or greater were selected and then exported into a new feature class. This feature class was then merged with the DHB feature class. In the same manner as for the demand points, the 65+ bed facilities were selected by corresponding DHB and exported into 20 new feature classes, one for each DHB.

The final data input required was the candidate facilities. The meshblock centroids chosen with the WLC process were merged with the DHB feature class. Using the select by attribute tool, the candidate facility points were selected by DHB and exported into new feature classes.

#### 4.3.2. Facilities and bed numbers

For each DHB, the number of facilities required had to be identified. The number of facilities for each scenario was determined by the total expected bed demand specified by Grant Thornton (2010) and the total projected population for 2026 (Statistics New Zealand, 2011).

Distribution of the whole population was used as a proxy for family of users of ARCFs. From that it was assumed that for every  $x$  number of people, there would be one aged residential care bed required. To calculate  $x$ , the total population of the study area (mainland North and South Islands) was divided by the total number of beds specified by the scenario. Using the value of  $x$ , the number of facilities required for each DHB could be calculated using the following formula, where  $F_D$  is the required number of facilities for the DHB in question:

$$F_D = \left\lceil \frac{P_D}{\left(\frac{P_T}{B_T}\right)} / C_{min} \right\rceil$$

Where  $P_D$  is the population of the DHB,  $P_T$  is the total population of the study area, and  $B_T$  is the total number of beds required for the population, and  $C_{min}$  is the minimum wanted capacity of the facility. For this project the minimum wanted capacity would be 1600 (80 beds\*20).

It is unlikely however that the returned value of  $F_D$  without the floor function would return an integer value. Therefore there is likely to be leftover, unallocated demand. Because there is a minimum capacity requirement, the number of facilities cannot be increased and left partially filled as they would not meet the required operating efficiency. Therefore, the capacity of the facilities have to increase to meet the demand. To calculate the number of beds required in each facility in each DHB, the following formula was used:

$$C_{max} = \frac{P_D}{\left(\frac{P_T}{B_T}\right)} / F_D$$

Where  $P_D$  is the population of the DHB, and where  $F_D$  is the required number of facilities for the DHB in question.

#### 4.3.3. Building and running the location-allocation models

Using model builder in ArcGIS, 40 separate location-allocation models were built - one per scenario per DHB. The required and candidate facilities stayed the same between scenarios for each DHB: the 65+ bed ARCFs within the relevant DHB's territory were added as 'required' facilities and the meshblock centroids chosen through the WLC process within the same area

were added as candidate facilities. The population points for each model were however unique, reflecting the differences in demand between the models. The demand score column for each population point was assigned as the demand point weight.

For each model, the number of facilities to find and the capacity of each facility was specified, and the direction of travel was set as 'demand to facility'. The models were then solved. Total computing to run all 40 models time was around 18 hours. The resulting facility point-data for each DHB, and each scenario, were then selected and exported into new feature classes. The feature classes were then merged, and the data exported to Excel for analysis. The process was then repeated for the routes data.

#### 4.4. Summary

This chapter explained the GIS methods used in this thesis. A couple of important factors need to be considered. First, the survey method used was not the method identified as most optimal in the methodology. Initially, it was hoped that the pairwise comparison method would be able to be used to determine the relative importance of each spatial attribute. However, with the pairwise comparison method for  $n$  attributes,  $n(n - 1)/2$  questions necessary to generate the weights (FERENCE, 1996). For the 15 attribute map layers in this study, 105 questions would need to be asked to calculate the size of the weights alone. Subsequently a seven point scale rating method was chosen to reduce the question load on respondents and potentially increase the number of respondents. This method allows just a single question to be asked for each attribute to obtain a relative importance value. Future research might consider using pairwise comparison test to generate the weights with a greater accuracy.

Second, limitations with the functionality of the location-allocation tool in ArcGIS 10.1 and constraints on computing power meant that an adapted location-allocation method had to be used. As demand at each demand point could only be located to a single facility, and the demand at many demand points exceeded the maximum space available at any facility, all demand points were duplicated 20 times, and the capacity of facilities expanded 20 times to allow demand to be split between multiple facilities. Future research might consider creating a demand point for each individual unit of demand and solving the analysis for each, or consider future generations of the software used.

## 5. Data

This study uses a number of disparate data sources. This chapter will describe the data used in the thesis, where it came from, how it was processed for use in this thesis and (where appropriate) the rationale for using a particular source over another. Each of these data sources are described in the following sections and summarised in Table 8. Unless explicitly stated all files were converted into feature classes using a New Zealand Transverse Mercator (NZTM2000) projection. The data used in this study were generally not available as GIS layers and much of the data was sourced via street addresses and then geocoded. As reliable transportation data from secondary islands was not available the study area was also defined as mainland North and South Islands. All data were split into North and South Island files, and data outside of these boundaries was excluded.

### 5.1. Digital boundaries

The first step was to collect the digital boundaries and define the study area. Digital boundary shapefiles for New Zealand census units, including area units (AU06)<sup>1</sup> and meshblocks (MB06) were downloaded from the Koordinates website (<http://www.koordinates.co.nz/>). The meshblock shapefile contained 42,946 unique meshblocks and the area unit shapefile contained 1,909 unique area units.

The area unit feature class was overlaid with a coastline polygon of New Zealand. Area units within mainland New Zealand were identified and exported to a new feature class. All area units outside of the mainland North and South Islands were excluded from the analysis. The meshblock feature class was then clipped by the mainland area unit feature class and the meshblocks within mainland area units were exported to a new feature class. The resulting mainland meshblock feature class contained 40,652 and the resulting area unit feature class contained 1,778 observations.

### 5.2. Aged residential care facilities (ARCFs)

The point locations and bed numbers of existing ARCFs in New Zealand were required. The data used by the Grant Thornton projections were not split by facility, and therefore not appropriate for this exercise, so data were sourced elsewhere. A list of ARCFs was obtained from the MOH upon data request. The list contained (among other variables) the names of each facility, the number of beds divided by service type, the address of the facility, and the

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<sup>1</sup> Area units are non-administrative areas defined by Statistics New Zealand. They are aggregations of meshblocks, the smallest NA areas defined by Statistics New Zealand. Area units fit between meshblocks and territorial authorities in size.

point coordinates of its location (WGS1984). The list was obtained in November 2011 and was up-to-date as of that year.

The bed number were split by service type into two categories, 'rest home' and 'hospital'. This classification differs from that used by the Grant Thornton review which split the residential care beds into four categories, 'rest home', 'hospital', 'dementia' and 'other'. The dataset contained 682 observation (facilities), with a total of 21,138 beds defined as 'rest home', and 13,571 beds defined as 'hospital' beds, summing to 34,709 beds in total. This compares to the 2008 base year numbers from the Grant Thornton review of 18,119 rest home beds, 9,821 hospital beds, 2,559 dementia beds, and 1,770 other beds, summing to a total of 32,269 beds, 2,440 beds fewer. Similarly the MOH dataset returned a total of 2,230 more beds than the Grant Thornton predicted 2011 higher-growth scenario (A) and 3,981 more than the lower-growth scenario (B) (see Table 7).

**Table 7: Bed numbers by service type and data source**

Bed type	MOH 2011 <sup>^</sup>	Grant Thornton 2008*	Grant Thornton 2011 (Scenario A)*	Grant Thornton 2011 (Scenario B)*
Rest home	21138	18119	16686	14917
Hospital	13571	9821	10679	10697
Dementia	N/A	2559	3060	3060
Other	N/A	1770	2054	2054
Total	34709	32269	32479	30728

Source: <sup>^</sup>Ministry of Health (2011), \*Grant Thornton, 2010,

The difference in numbers may stem from the data collection methods. Grant Thornton (2010) collected data from the Client Claims Processing System (CCPS) and projects using Organisation for Economic Cooperation and Development (OECD) trends. The MOH data is collected from aged residential care audits, which occur every two years. This long period may cause some latency, and mean that the number of beds recorded may be up to two years out of date.

The difference in service type classification is more difficult. Comparing a sample of the MOH data to that recorded on the Eldernet website (<http://www.eldernet.co.nz/>), it appears that the total number of beds recorded for a facility remains approximately the same, but there does not seem to be any consistency as to whether the dementia care beds fall under the MOH's 'rest home' or 'hospital' categories. For this reason, it seems sensible to not split the analysis by service type, but instead analyse the aged residential care population as a whole. In the future, if more detailed/reliable data can be obtained, the study could be rerun split by facility type.

The dataset was opened in ArcGIS and the coordinates generated using the 'display XY data' function, using World Geodetic System 1984 (WGS1984). The resulting point shapefile was then imported into a new feature class, and transformed into NZTM2000.

### 5.3. Population points

New Zealand North and South Island population projection data was required for both the present day and for 2026. Population by administrative unit was obtained from the Statistics New Zealand website in the form of an Microsoft Excel spreadsheet (<http://www.stats.govt.nz/>). The population data came in the form of quinquennial projections, starting at 2011 and projecting until 2031. The finest available aggregation was 2006 area units (AU06)<sup>2</sup>. For this reason, area units were used for analysis.

Both the travel time to nearest provider and the location-allocation analyses require that the population data be in the form of a point feature class. As population was only available down to Area Units, centroids of each area unit were generated to represent each population point. The 'mean centre' tool in ArcGIS would give the exact middle point of each area unit, but this point was not necessarily representative of the location of the populations within the area unit. Instead, meshblock mean centres were generated and the mean centre was then found for all the meshblock centroids within each area unit. This allowed the mean centre of the area unit to be weighted by the meshblock locations, giving a more accurate representation of the population location within the area unit. The resultant data was then saved as a new point feature class.

The population projection table was then opened in ArcGIS. The table was then joined to the point feature class based on AU06 value.

### 5.4. Road network

The road network geodatabase used was produced by New Zealand Open GPS project (<http://nzopengps.org/>) and sourced from Ollivier and Company (<http://www.ollivier.co.nz/>).

The geodatabase contained two feature classes that were used to generate an ArcGIS compatible road network: 'roadclass' (a polyline feature class of the complete road centrelines of New Zealand) and 'node1' (a point feature class of all intersections with a hierarchy for identifying overpasses and tunnels etc.). The 'roadclass' feature class contained a variable classified each road line into one of seven different classes, each representing a different travel speed. Before the feature class could be used to generate a road network, these classes had to

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<sup>2</sup> Data was requested by meshblock (the finest administrative unit) but was not available for privacy reasons.

be converted into likely travel times across each polyline. Three new fields were added: speedtype, speed\_m\_per\_m, and minutes. Speedtype was populated with the same data as the roadclass classification variable, and then reclassified into appropriate speed for that classification (in kph) along the road network. speed\_m\_per\_m was populated as the speed along the section of the network in meters per second ( $\text{speedtype} \times 1000 / 60$ ). The minutes variable was then populated with the time taken to traverse that element ( $\text{shape\_length} / \text{speed\_m\_per\_m}$ ).

The two feature classes were split into North and South Island feature classes. Network datasets were then created for each of the North and the South Islands using the network analysis extension. Road networks were then built from each network dataset.

The North and South Island networks were then checked for errors. To identify errors in the network, service area analyses were run for various data points to identify non-traversable elements. Missing nodes or incomplete data points were then manually created in the ArcGIS editor. The road network were then rebuilt and a new service area analysis was rerun. The process was continued until satisfied that all non-traversable elements were identified and corrected. The road networks were then rebuilt for a final time.

## 5.5. Comparison data

To compare access between rural and urban areas and between DHBs administrative concordance data was required.

### 5.5.1. Urban/rural

While there is no official urban/rural classification in New Zealand, urban and rural areas are defined by the Statistics New Zealand urban/rural profile (Statistics New Zealand, n.d.). These classifications were used to represent urban and rural areas in New Zealand. A Microsoft Excel document of urban/rural classification concordance with meshblocks was also downloaded from the Statistics New Zealand website. The Profile classifies each meshblock into one of 8 categories:

1. Main urban areas
2. Satellite urban areas
3. Independent urban areas
4. Rural areas with high urban influence
5. Rural areas with moderate urban influence
6. Rural areas with low urban influence
7. Highly rural/remote areas



## 8. Area outside urban/rural profile.

The first three classifications represent urban areas and the next five represent rural areas. The urban/rural concordance table was joined to the mainland meshblock feature class and exported to a new feature class.

### 5.5.2. New Zealand Deprivation Index (NZDep2006)

The New Zealand Deprivation Index 2006 (NZDep2006) is small-area index of relative socio-economic deprivation (Salmond & Crampton, 2012). NZDep2006 assigns a deprivation value to each meshblock in New Zealand based on a deciles system. For example, a value of 10 indicates that the meshblock is in the most deprived 10 percent of areas in New Zealand, while a value of 1 indicates the meshblock is in the least deprived 10 percent of areas. A shapefile of meshblocks classified by NZDep2006 was downloaded from the Koordinates website. The shapefile contained 42,946 unique polygons mirroring the meshblock shapefile in section 5.1.

### 5.5.3. District Health Boards (DHBs)

A shapefile of New Zealand DHBs was downloaded from the Koordinates website. The shapefile contained the 20 DHBs as polygons.

## 5.6. Spatial attributes

In the methods chapter (section 4.2.1), 15 spatial attributes were identified as being of likely importance to spatial decision makers when deciding where to place an ARCF. These attributes are summarised below. Sufficient data was not available to generate spatial attribute maps for all the attributes. Data was only available for nine of the spatial attributes. The data collection for each of these nine attributes is detailed below and summarised in Table 8.

### 5.6.1. 24-Hour emergency departments

No up-to-date list of hospitals with 24-hour emergency departments was identified. Hospitals with 24-hour emergency services were therefore identified with a manual search of the each of the DHB websites. 27 hospitals were identified as having a 24-hour emergency department. These hospitals were then selected from the public hospital feature class created for the public hospital spatial attribute and were exported as a new feature class.

### 5.6.2. Fire stations

A point shapefile of all fire station locations, volunteer and professional, was accessed from the Koordinates website. The shapefile was created by Zenbu (<http://www.zenbu.com/>), most recently updated November 2011, and contained 443 observations.

### **5.6.3. Public hospitals**

A list of public hospitals names in New Zealand was accessed from the MOH website. The list identified 40 public hospitals. A Microsoft Excel file was created containing the each of the hospital names. An address for each of these hospitals was then gathered with through an internet search, and inputted into the Excel file. The list of addresses was then imported into a freeware batch geocoder running off the Google Maps application programming interface (API) (<http://apitricks.blogspot.co.nz/2008/10/batch-geocoder-with-csv-output.html>). The addresses were outputted as coordinates in CSV format (longitude, latitude, 'address'). The batch geocoder has a viewing screen to which allows you to see where it plotted the coordinates on Google Maps. Resultant coordinates were visually checked for sense in the viewer window. The CSV results were copied back into the excel document and split into rows using the text to columns tool, with comma delimitation.

The excel file was then opened in an ArcGIS map document. The locations were in the map document generated using the 'display XY data' function.

### **5.6.4. General Practitioners (GPs)**

A list of general practice names, addresses and coordinates was provided by the MOH in 2011. The Microsoft Excel document was opened in ArcGIS and the point locations generated using the 'display XY data' function.

### **5.6.5. Dentists**

No complete list of dental providers in New Zealand was identified. The volume of dental surgeries in New Zealand meant that collecting names and addresses individually from internet searches was unfeasible.

The best available source was the health facility register compiled by the New Zealand Health Information Services (NZHIS). The list collected the names and addresses of all health facilities in New Zealand with the intention of creating a complete register, and assigning each facility with a unique health facility code. The project was however apparently not continued after the disestablishment of the NZHIS. While the list supposedly contains the names of all medical services in New Zealand, it appears that many facilities are missing - in particular ARCFs. Personal correspondence with the MOH suggested that the dental surgery data should be reasonably accurate.

The reasons for the incompleteness of the list are not clear. A lack of a variable to identify the type of facility meant that another system of identifying dentists would have to be used. Key word searches were made for words commonly used in dentistry surgery names. A search of

Wellington dental facilities yielded a list of common words, or parts of words. Observations that contained any of the following were selected and imported into a new Microsoft Excel document: “dent”, “oral”, “orth”, “mouth”, “smile” or “teeth”. A visual search was then undertaken of the original document to identify any obvious missed facilities, and a search of the new document was then undertaken for obviously unsuitable facilities (i.e. ‘dent’ appearing as part of ‘accident’ etc.). This process yielded a list of 727 dental facilities. The addresses were then imported into the batch geocoder and the resultant coordinates imported back into the excel document.

#### **5.6.6. Psychiatrists**

A list of all Doctors current registered with the Medical Council of New Zealand with an identified vocational scope of ‘psychiatry’ was downloaded from the Medical Council of New Zealand website (<http://www.mcnz.org.nz/support-for-doctors/list-of-registered-doctors/>). The list contained their name, the district in which they work, and the expiry date of their registration.

After removing duplication where individuals had changed their names, (the register records both original names and new names), the initial download consisted of 561 unique individuals. A further 21 names were excluded where district data were not recorded, or the address given was overseas.

The remaining 540 observations were then copied into the batch geocoder. Results were visually checked for sense in the program window. The resulting coordinates were imported back into the Excel document.

#### **5.6.7. Electricity distribution lines**

A Land Information New Zealand (LINZ) created shapefile of New Zealand transmission lines was downloaded from the Koordinates website. The shapefile, created in 2007, seemingly contained the polyline data for all transmission lines in New Zealand outside of the urban centres. Inside the urban centres however, there were very few recorded transmission lines. No more-complete data could be found.

As electricity transmission lines generally follow street grids, the polylines of urban streets were used as a proxy for urban electricity distribution lines. A shapefile of New Zealand urban areas was downloaded from the Koordinates website. The New Zealand road centrelines feature class was then clipped by the urban areas shapefile and the resulting urban polylines were exported to a new feature class. This was then merged with the New Zealand transmission lines and exported as a new feature class.

#### 5.6.8. Access Roads

To identify roads that would provide suitable access to ARCFs a pair of service area analyses were run in ArcGIS using the network analyst extension, first for the North and then for the South Island.

For each, the corresponding road network was opened in ArcGIS and a new service area analysis layer was created. A point feature class was created and a series of points were placed on a road known to be accessible in each of the main centres about the island. These points were then assigned as the facilities for the analysis. A travel impedance of 4 hours was set, and the output was set to 'true lines'. A restriction of 'not for cars' was used so to exclude 4wd, pedestrian and service only roads. The service area analysis was then solved and the resultant line output was exported as a new feature class into the geodatabase. These two new feature classes represented all the accessible roads in New Zealand that were suitable as access roads.

#### 5.6.9. Taxi or shuttle depots

No comprehensive list of taxi or shuttle providers in New Zealand was identified. Data therefore had to be manually collected. A list of names and addresses of taxi companies affiliated with the New Zealand taxi federation was available on its website. 51 individual taxi company names and addresses were obtained from this list. However this list accounted for a minority proportion of the taxi providers in New Zealand. A category search for "Taxi" on the Yellow Pages website returned 219 hits nationwide. Results were then assessed and added to the taxi federation list. Companies that had multiple locations, i.e. Auckland and Wellington were split into separate observations. After double-ups and unsuitable results were excluded, there were 167 observations.

Some results contained addresses as well as phone numbers, but many did not. Where companies had addresses recorded, they were entered into the list. For companies that did not have addresses recorded, an internet search was used to find them. For several of the companies, only a region and not an address was found. For these, the region was entered in as the address and thus the resultant coordinates after geocoding would give the centre of the region as a proxy for the unavailable address. The addresses were then imported into the batch geocoder and the resultant coordinates imported back into the document as new variables. The excel file was then opened in an ArcGIS map document. The locations were in the map document generated using the 'display XY data' function and then imported into a new feature class.

## 5.7. Summary

The data collated for this project relies on a number of different sources. Metadata for each is limited and many were not available as geographic layers. The data used is summarised below (Table 8) and maps of the population, ARCF locations and the comparison data are available in Appendix three.

Table 8: Data description

Desired data	Input data	Input data format	Source	Year	Output format	Output details
ARCF locations and bed numbers for 2011	ARCF locations with bed numbers, addresses and coordinates	List (Excel document)	MOH	2011	Point feature class	682 observations (facilities), with a total of 21,138 beds
New Zealand mainland population points for 2011 and 2026	Quinquennial population projections by area unit, 2006-2031	List (Excel document)	Statistics New Zealand	Undated. Accessed June 2011	Point feature class	1,778 population points
New Zealand mainland digital boundaries	Area unit (AU06) digital boundaries	Shapefile	Statistics New Zealand	Undated. Accessed June 2011	Polygon feature class	1,778 polygons
Urban/rural classified meshblocks	Meshblock (MB06) digital boundaries	Shapefile	Statistics New Zealand	Undated. Accessed June 2011	Polygon feature class	40,652 polygons
	Urban/rural concordance with meshblocks	List (Excel document)	Statistics New Zealand	Undated. Accessed 2011	Polygon feature class	8 categories of urban/rural classification 40,652 polygons
New Zealand Deprivation Index (NZDep2006)	NZDep2006 digital boundaries	Shapefile	Otago University, accessed via Koordinates website MOH	2007	Polygon feature class	40,652 polygons
District Health Board (DHB)	DHB boundaries	Shapefile		2012	Polygon feature class	20 polygons
24-hour emergency department locations	24-hour emergency department locations	Manually entered from website	DHB websites	2013	Point feature class	27 point locations
Fire station locations	Fire station locations	Shapefile	Zenbu, accessed via Koordinates website	2011	Point feature class	443 point locations

Public Hospital locations	Public Hospital locations	List	MOH	2012	Point feature class	40 point locations
GP locations	GP locations	List with coordinates	MOH	2011	Point feature class	970 point locations
Dentist locations	Dentist locations	List	New Zealand Health Information Service, MOH	Undated. Accessed 2011	Point feature class	727 point locations
Psychiatrist locations	Psychiatrist locations	List	Royal New Zealand College of General Practitioners	2013	Point feature class	540 point locations
Electricity distribution lines locations	Electricity distribution line locations	Shapefile	Land Information New Zealand, accessed from Koordinates	2007	Polyline feature class	Polylines
Access road locations	Access road locations	Shapefile	New Zealand Open GPS project, accessed from Koordinates	2011	Polyline feature class	Polylines
Taxi depot locations	Taxi depot locations	List	New Zealand Taxi Federation, the Yellow Pages website	2013	Point feature class	167 point locations





## 6. Results

This chapter presents the results of the analyses described in the methods chapter. As with methodology and methods chapters, this chapter is split into three parts corresponding with the three objectives of the thesis. Part one will present the results of the spatial accessibility measurement. Part two will present the results of the survey of aged residential care providers and the subsequent suitability analysis to identify locations suitable for the construction of ARCFs. Part three will present the results of the location-allocation analyses to suggest future locations.

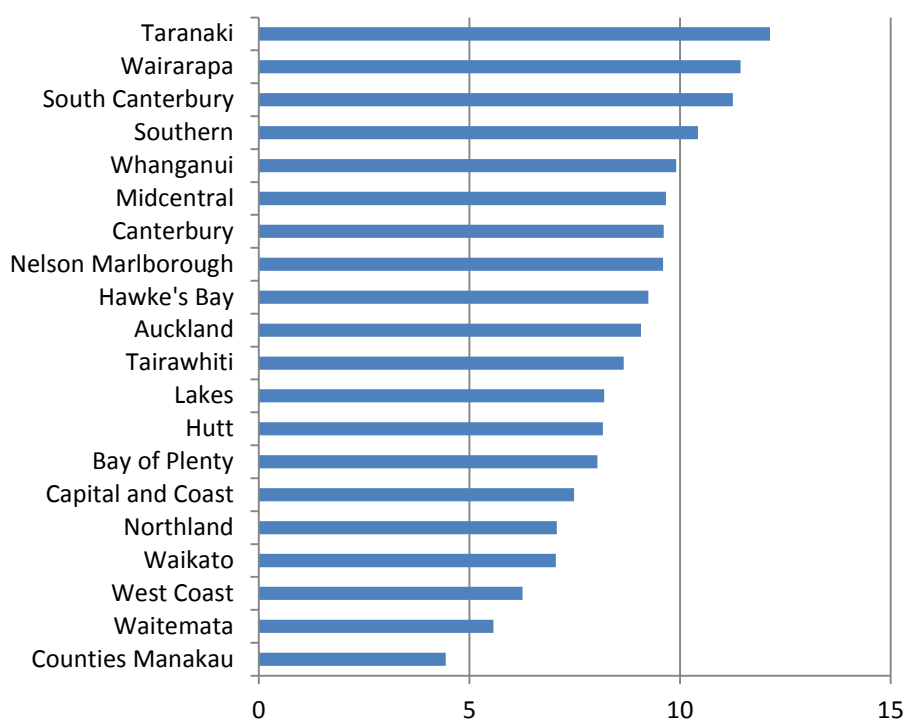
### 6.1. Part 1: Measuring current spatial accessibility

In this section, the spatial accessibility of existing ARCFs is described and measured.

#### 6.1.1. Bed-to-population ratios

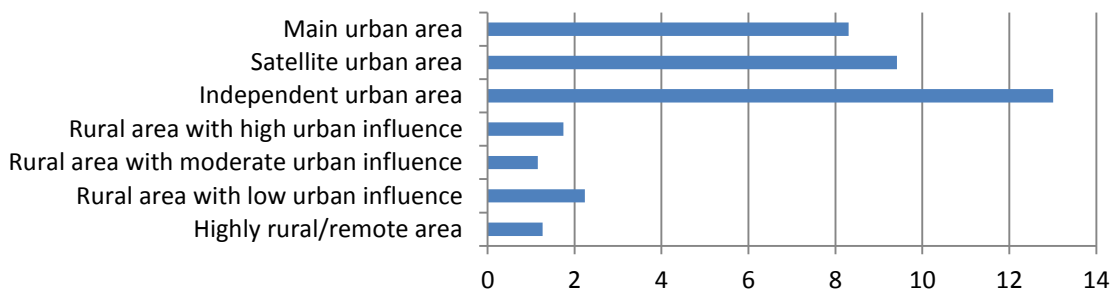
Considerable variation was observed in bed-to-provider ratios between DHBs (Figure 8).

Figure 8: ARCF beds per 1000 people, by DHB



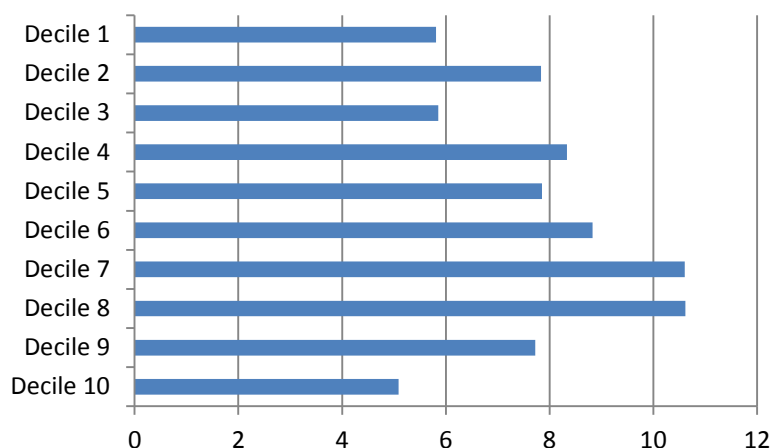
Nationally, the aged residential care bed to population rate in 2011 was 8.0 beds per 1000 people. Of the 20 DHBs in New Zealand, 12 exceeded the national rate. Taranaki had the highest rate at 12.1 or over 50% greater than the national rate. Counties Manukau had the lowest rate at 4.4 beds per 1000 people, nearly 50% below the national rate. When split by urban/rural category, each of the urban categories exceeded the national rate and each of the rural categories scored significantly less (Figure 9).

Figure 9: ARCF beds per 1000 people, by urban/rural category



Main urban areas (8.3) and satellite urban areas (9.3) were above but broadly consistent with the national rate. Independent urban areas (13.0) however, had a rate over 60% higher than the national rate. Rural areas were each less than 30% of the national rate. Variation between the NZDep06 deciles was also pronounced, but the pattern of variation was less evident (Figure 10).

Figure 10: ARCF beds per 1000 people, by NZDep06 deciles

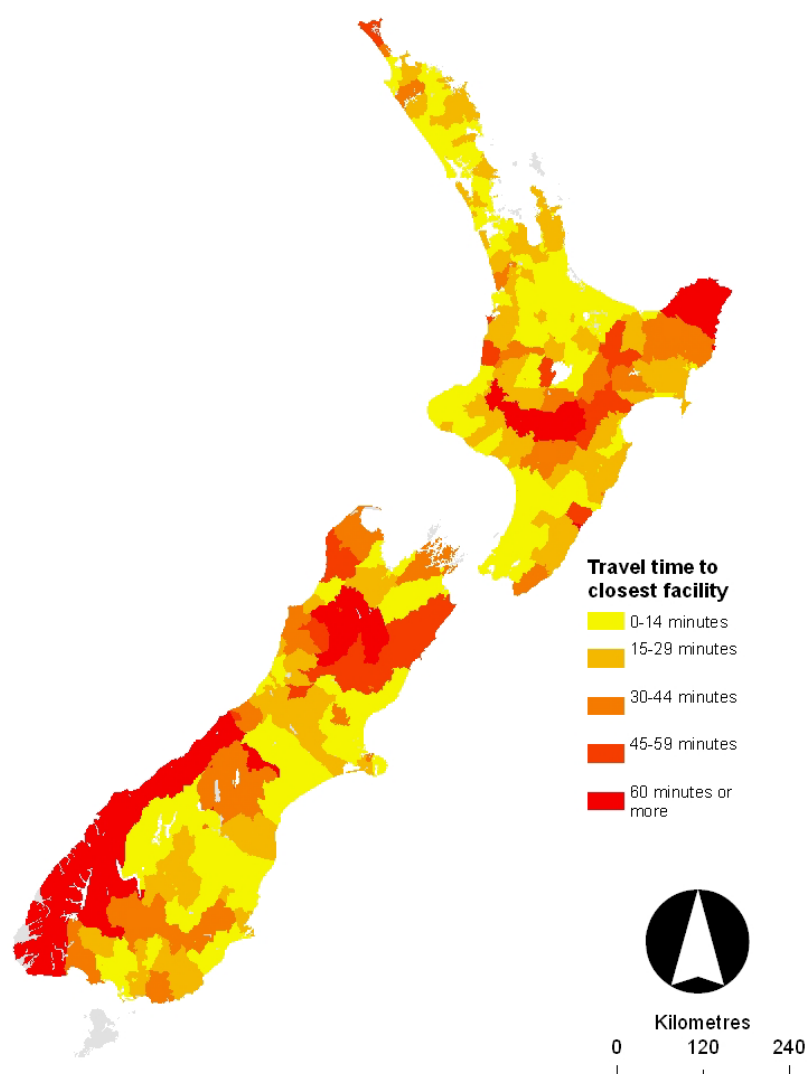


Bed-to-population ratios by decile varied from 65% to 135% of the national rate. Ratios were lowest in the least deprived (decile 1) and most deprived areas (decile 10). Decile 10 had the lowest rate at 5.1 beds per 1000 people. However, three of the five most deprived deciles had ratios above the national average, while four of the least deprived deciles were below the national average. Deciles 7 and 8 had the highest ratios at 10.6 each.

### 6.1.2. Travel time to nearest facility

Travel time to the nearest ARCF were calculated for each area unit population point. The results were categorised and displayed as a map below (Figure 11). More detailed maps of travel time to closest facility displayed by DHB can be found in Appendix four. These more detailed maps show local spatial variation which is obscured at this scale.

Figure 11: Travel time to closest ARCF by area unit, 2011



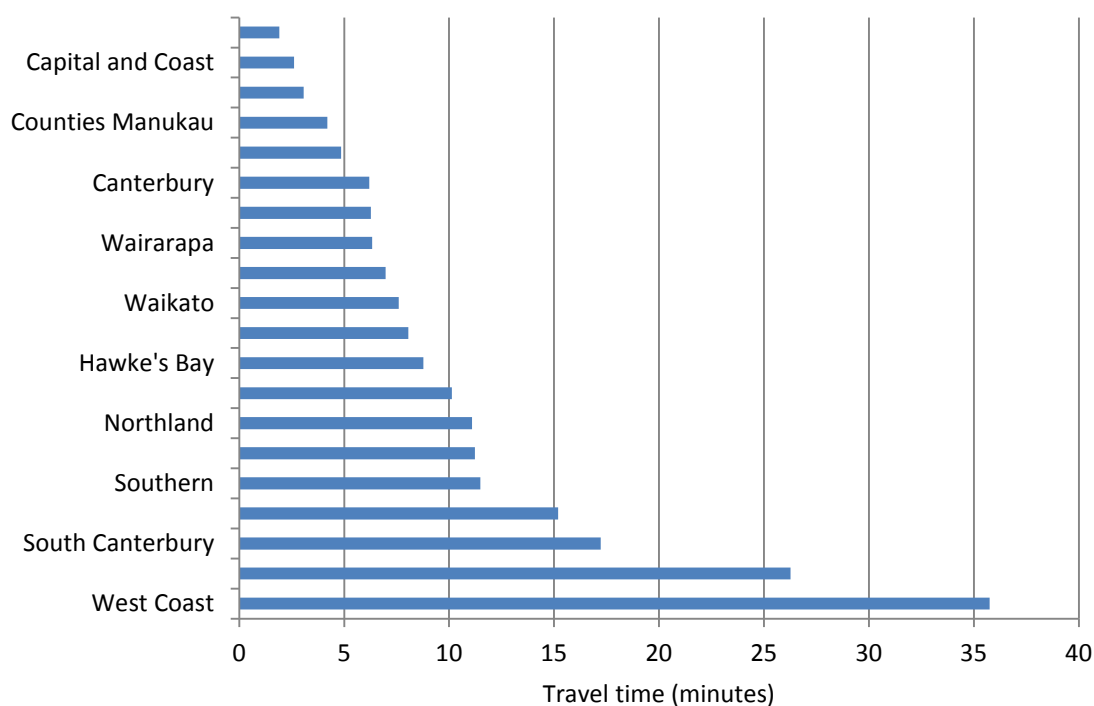
It is evident that travel times to the nearest facility are substantial in some regions of New Zealand. The West Coast and Southland, Tasman and Marlborough, Manawatu-Whanganui, and Gisborne regions all have significant areas where travel time is over 60 minutes. Smaller pockets exist in Canterbury, Otago, Bay of Plenty, Northland and Waikato regions. Significant proportions of the same regions have closest facility travel times between 45 and 59 minutes. Auckland and Taranaki regions appear to have travel time predominantly less than 15 minutes, with a scattering between 15 and 29. Wellington is similar, but with pockets of greater travel times in the south west of the region. When summarised by DHB, the differences in travel time between areas becomes very pronounced (Table 9).

Table 9: Summary of travel times to closest facility by DHB

DHB	Travel time (minutes)		
	Min	Max	Average
Auckland	0.12	5.46	1.91
Bay of Plenty	0.05	63.63	8.05
Canterbury	0.01	69.84	6.19
Capital and Coast	0.02	12.17	2.61
Counties Manukau	0.19	29.65	4.20
Hawke's Bay	0.25	54.95	8.77
Hutt	0.28	10.93	3.06
Lakes	0.02	46.35	10.13
Midcentral	0.11	75.61	6.98
Nelson Marlborough	0.37	144.31	11.23
Northland	0.03	55.55	11.08
South Canterbury	0.19	121.38	17.22
Southern	0.00	163.26	11.49
Tairāwhiti	0.97	129.56	26.27
Taranaki	0.08	71.72	6.28
Waikato	0.00	59.36	7.60
Wairarapa	0.44	30.95	6.34
Waitemata	0.19	37.09	4.85
West Coast	0.18	219.07	35.75
Whanganui	0.15	104.72	15.20

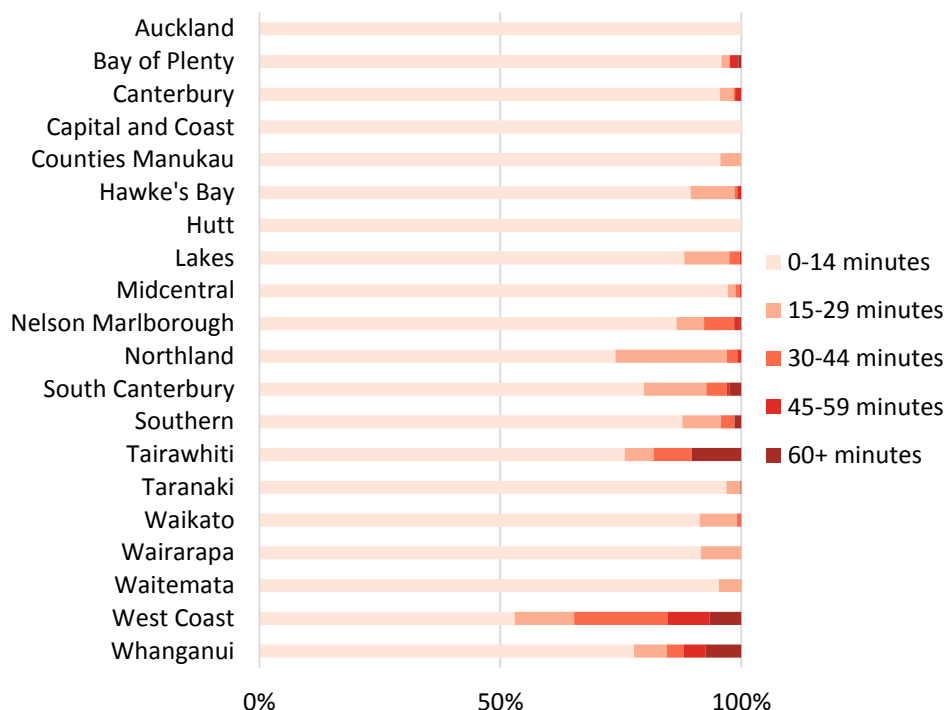
All DHBs recorded a minimum travel time of less than one minute. The maximum travel times ranged from just over five minutes in Auckland, and nine minutes for Capital and Coast, to over 3.5 hours for West Coast. Average travel times also showed considerable variation (Figure 12). Auckland again had the lowest average at sub-two minutes, followed by Capital and Coast (2.6), Hutt (3.1) and Counties Manukau (4.2). The lowest average in the South Island was for Canterbury with 6.2, just below Nelson Marlborough at 11.2 and Southern at 11.5. The West Coast had the highest average travel time by some margin at 36.8 minutes.

Figure 12: Average travel time to closest facility by DHB, 2011



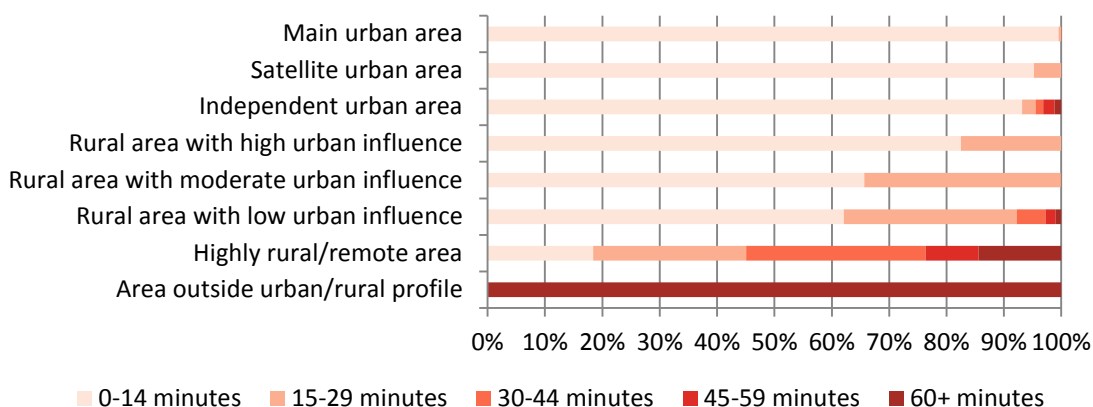
To compare the distribution of travel times within each individual DHB, urban/rural profile category and deprivation decile they were each graphed against population and travel time. An impressive 93% of the population live within 15 minutes of a facility and 98% with half an hour. However two percent live over half an hour away, and half a percent over an hour. Travel time was graphed against population and DHB (Figure 13).

Figure 13: Proportion of population by travel time to closest ARCF (minutes) and DHB, 2011



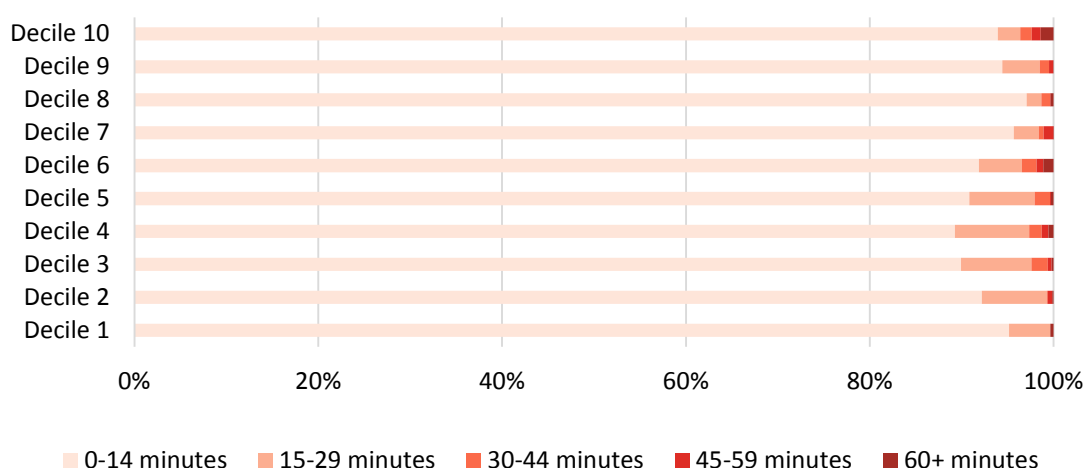
In all DHBs the majority of the population was within 15 minutes of the nearest ARCF. In Auckland, Capital and Coast and Hutt DHBs the entire population was within 15 minutes. As might be expected with the highest average travel times, West Coast DHB had the highest proportion of residents over 15 minutes from a facility (47%), the highest over 30 minutes (35%) and the highest over 45 minutes (15%). Tairāwhiti had the next highest proportion over 30 minutes (18%) and the highest proportion over 60 minutes (10%). Fifteen percent of the population of Whanganui DHB were over 30 minutes from a facility and 7% over one hour. When the distribution of population by travel time was graphed urban/rural profile the results were dramatic (Figure 14).

Figure 14: Proportion of population by travel time to closest ARCF (minutes) and urban/rural profile, 2011



As with bed-to-population ratios (Figure 9) there was marked variation between urban and rural categories. Travel time increased as urban influence decreases. None of the population located in main or satellite urban areas had to travel more than 30 minutes to reach the nearest ARCF. Five percent of the population on independent urban areas had to travel more than 30 minutes, and one percent had to travel more than one hour. In rural areas with high urban influence, none of the population had to travel over 30 minutes, but the proportion travelling over 15 minutes is 17%. In rural areas with moderate urban influence that proportion increase to 34%. The proportion continues to increase with increasing rurality until areas outside the urban/rural profile where the entire population has to travel an hour or more. As with bed-to-population ratios, there was some variation between deprivation deciles but the pattern of variation unclear (Figure 15).

**Figure 15: Proportion of population by travel time to closest ARCF (minutes) and NZDep2006, 2011**



Travel times to nearest facility were less than 15 minutes for 89% of the population in each of the deciles and 97% and 96% in Deciles 8 and 7 respectively. Travel times over an hour accounted for only one percent or less in each of the deciles.

To further investigate the patterns of variation between urban/rural category and between deprivation deciles a series of multivariate regressions were used (Table 10). For the regressions deprivation was re-categorised into quintiles and main urban areas and the middle deprivation deciles were excluded.

**Table 10: Regression results: Travel time to nearest facility by urban/rural category and deprivation quintile**

Variable	Model		
	Urban/Rural category	Deprivation quintile	Urban/Rural category and deprivation quintile
Constant	2.813 (0.000)*	9.970 (0.000)*	2.723 (0.000)*
Satellite urban area	1.325 (0.448)	-	1.313 (0.452)
Independent urban area	3.972 (0.000)*	-	4.019 (0.000)*
Rural area with high urban influence	6.706 (0.000)*	-	6.650 (0.000)*
Rural area with moderate urban influence	9.583 (0.000)*	-	9.777 (0.000)*
Rural area with low urban influence	14.672 (0.000)*	-	14.823 (0.000)*
Highly rural/remote area	35.650 (0.000)*	-	42.836 (0.000)*
Area outside urban/rural profile	12.730 (0.000)*	-	151.086 (0.000)*
Deciles 9-10	-	-3.249 (0.008)*	0.380 (0.676)
Deciles 7-8	-	-0.264 (0.830)	-0.569 (0.526)
Deciles 3-4	-	-2.898 (0.018)*	-0.495 (0.581)
Deciles 1-2	-	-1.101 (0.369)	0.954 (0.287)
R2	0.476	0.007	0.477
N	1753	1753	1753

Main urban areas and Deciles 5-6 excluded

\* denotes statistical significance (p<0.05)

When run independently, there was a clear association between urban/rural category and travel time to nearest facility. Each increase in rurality was associated with an increase in travel time and the increase in all but satellite urban areas were statistically significant. There was also apparent association between deprivation quintile and travel time. Most deprived areas (deciles 9-10) were associated with the lowest travel time, followed by the second least deprived areas (Deciles 3-4). Both of these associations were found to be statistically significant.

However when combined into a single regression, the associations between urban/rural category and travel time was strengthened and between deprivation and travel time was weakened. Each increase in rurality was again associated with an increase in travel time and the increase in all but satellite urban areas were statistically significant. When controlled for



urban/rural category the differences between deprivation deciles almost disappear. Average travel times vary less than 1.5 minutes and none of the variations are statistically significant.

### **6.1.3. Summary**

Considerable variation in both measures of availability and accessibility were seen between DHBs. Provider-to-population ratios by DHB varied by up to 50% above and below the national average. Average travel times to nearest facilities by DHB ranged from just two minutes to over 30, and maximum travel times ranged from just 5 minutes to over 3 and half hours. More rural DHBs typically had poorer accessibility than more urban DHBs. West Coast, Whanganui, Tairāwhiti and South Canterbury consistently scored poorly relative to other DHBs in measures of accessibility. Auckland, Capital and Coast, Counties Manukau and Hutt DHBs on the other hand all scored highly.

Inequity in spatial access was seen between urban/rural category. More rural areas had consistently higher travel times than more urban areas and (for all but satellite urban areas) the increases in travel time were shown to be statistically significant. However, limited variation was found when aggregating by deprivation. Average travel times were lowest where deprivation was the highest and where deprivation was the lowest. However the variations were generally not statistically significant and when controlled for urban/rural category none of the variation was found to be statistically significant.

## **6.2. Part 2: Identifying potential locations**

This section will present the results of the analysis to identify potential locations for ARCFs in the future. As described in the methods chapter, the exercise consisted of three stages. First, decision makers in the aged residential care industry were surveyed to determine the value they placed on certain spatial attributes when determining where to place an ARCF. Second, spatial attribute maps were generated for each attribute, and combined using a WLC method to generate a 'surface of acceptability' for potential ARCF placement. Third, point locations were generated from the 'surface of acceptability' to represent suitable areas, and to use in Part 3.

### **6.2.1. Survey**

As described in the methods chapter (section 4.2.3), seven decision makers from ten providers responded to the survey. Their responses are reported below.

#### 6.2.1.1. *Demographics*

As this was an anonymous survey and potentially commercially sensitive, demographic questions were kept broad and made optional. Six respondents recorded the number of ARCFs that their organisation operated (see Table 11).

**Table 11: Number of responses by organisation size**

Number of facilities operated	Freq.	Percent
1	3	50
2-5	1	17
6-9	0	0
10 or more	2	33
Total	6	100

Half of the respondents were from organisations that operated a single facility. One respondent was from an organisation between two and five facilities, and two were from larger organisations with 10 or more. All seven respondents recorded whether their organisations were for- or not-for-profit (see Table 12).

**Table 12: Number of responses by organisation type**

Organisation type	Freq.	Percent
For profit	1	14
Not for profit	6	86
Total	7	100

Six of the seven respondents identified their organisation as being not-for-profit, and only one identified as for-profit.

#### 6.2.1.2. *Importance of spatial attributes*

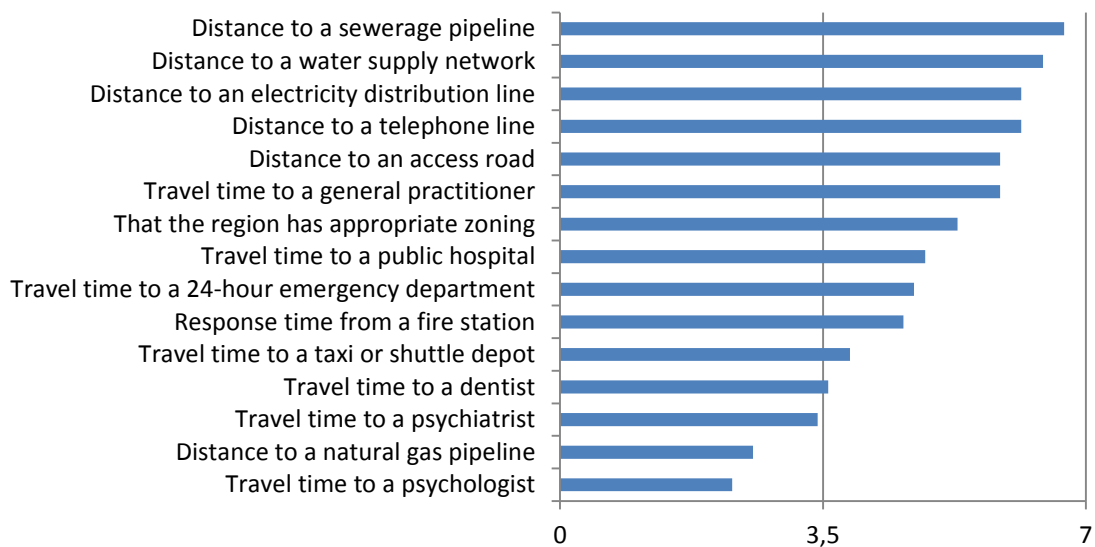
Respondents were asked to rank on a seven point scale the relative importance of 15 spatial factors when deciding where to place an ARCF, with a value of one being 'relatively unimportant' and seven being 'very important'. The questions were grouped into five categories: emergency response, associated health services, utilities, zoning, and transport. By design, each of these questions was compulsory for respondents and as such all respondents recorded scores between 1 and 7 for each of the questions. The results are summarised below (Table 13).

Table 13: Summary of questionnaire responses about importance of spatial attributes

	Spatial attribute	Min	Mean	Max
Emergency response	Travel time to a 24-hour emergency department	2	4.7	7
	Response time from a fire station	1	4.6	7
Associated health services	Travel time to a public hospital	2	4.9	7
	Travel time to a GP	5	5.9	6
	Travel time to a dentist	1	3.6	7
	Travel time to a psychologist	1	2.3	4
	Travel time to a psychiatrist	1	3.4	7
Utilities	Distance to a water supply network	6	6.4	7
	Distance to a sewerage pipeline	6	6.7	7
	Distance to a natural gas pipeline	1	2.6	4
	Distance to a telephone line	4	6.1	7
	Distance to an electricity distribution line	4	6.1	7
	Distance to an access road	4	5.9	7
Zoning	That the region has appropriate zoning	4	5.3	7
Transportation	Travel time to a taxi or shuttle depot	2	3.9	6
Total		-	4.8	-

The spatial attribute questions relating to emergency response had varied answers. Travel time to a 24-hour emergency department and response time from a fire station had minimum values of two and one respectively, and both had maximum values of seven. The mean importance of each however, was above four (the mid-point on the seven point scale), suggesting that both were of importance to spatial decision makers when deciding on a location (Figure 16).

Figure 16: Mean importance of spatial attributes in decision making



Likewise, the associated health services spatial attribute questions had responses from both ends of the scale. Travel time to a dentist, travel time to a psychologist, and travel time to a psychiatrist all had minimum responses of one, and travel time to a public hospital had a minimum response of two. Travel time to GP on the other hand had a much higher minimum value of five. Travel time to a GP had the highest mean travel time of 5.86, and travel time to a psychologist had the lowest at just 2.29 - the lowest of any attribute.

The utilities spatial attributes were generally the highest rated of all the spatial attributes. Distance to a water supply network, distance to a sewerage pipeline, distance to a telephone line, distance to an electricity distribution line and distance to an access road were all scored highly, with minimum scores of 6, 6, 4, 4 and 4 respectively. All were given a score of seven by at least one respondent, and all but distance to an access road (5.86) had mean scores greater than six. Distance to a natural gas pipeline was the exception, being scored lowly by all respondents with a minimum score of one, a maximum of four and a mean of just 2.57.

That the potential location had appropriate zoning was also important to the respondents. The minimum given score was four, and the maximum was seven. The mean score was 5.29, the second highest of the categories, after utilities. Transport was less important, with travel time to a taxi or shuttle depot scoring between two and six, and a mean score of 3.86.

#### 6.2.1.3. *Identifying attribute values*

For each of the emergency response, associated health services and transportation spatial attributes, respondents were asked what the maximum travel time from that attribute would be for them to be comfortable placing an ARCF. Respondent were asked to record the travel time in minutes. The results of this section are summarised below (Table 14).

Table 14: Maximum acceptable travel time from each attribute (minutes), by respondent

Category	Attribute	Respondent						
		1	2	3	4	5	6	7
Emergency response	Travel time to a 24-hour emergency department	30	30	60	240	15	15	120
	Response time from a fire station	30	15	10	60	10	5	60
Associated health services	Travel time to a public hospital	30	30	60	120	15	30	180
	Travel time to a GP	20	15	60	30	15	15	30
	Travel time to a dentist	60	30	60	1440	30	30	240
	Travel time to a psychologist	120	300	120	10080	60	60	480
	Travel time to a psychiatrist	120	30	120	10080	60	60	480
Transportation	Travel time to a taxi or shuttle depot	15	30	120	60	20	15	480

Acceptable travel times for the respondents ranged from 5 minutes to a week. However, with the exception of one respondent, all attributes were given travel times of 8 hours or less. Response time from a fire station and travel time to a GP had the shortest acceptable travel times by some distance: with a lowest time of 5 and 15 minutes, highest times of 60 and mean times of 27 and 26 minutes respectively. Travel time to a public hospital, travel time to a 24-hour emergency department, and travel time to a taxi or shuttle depot had the next shortest acceptable travel times, with median times of 30 or less. Travel time to a dentist, psychologist and psychiatrist had the longest acceptable travel times with medians of 60, 120 and 120 respectively.

Travel time thresholds were then identified for each of the spatial attributes (Table 15). As explained in more detail in the method chapter, a threshold was developed for each time specified for each spatial attribute. The thresholds were also given a score based on the number of respondents that would be happy with that distance.

Table 15: Travel time thresholds by spatial attribute

	Thresholds					
	1	2	3	4	5	6
Maximum acceptable travel time to a 24-hour emergency department (minutes)	240	120	60	30	15	-
Proportion of respondents accepting travel time	14. 3%	28. 6%	42. 9%	71.4 %	100. 0%	-
Maximum acceptable response time from a fire station (minutes)	60	30	15	10	5	-
Proportion of respondents accepting travel time	28. 6%	42. 9%	57. 1%	85.7 %	100. 0%	-
Maximum acceptable travel time to a public hospital (minutes)	180	120	60	30	15	-
Proportion of respondents accepting travel time	14. 3%	28. 6%	42. 9%	85.7 %	100. 0%	-
Maximum acceptable travel time to a GP (minutes)	60	30	20	15	-	-
Proportion of respondents accepting travel time	14. 3%	42. 9%	57. 1%	100. 0%	-	-
Maximum acceptable travel time to a dentist (minutes)	144 0	240	60	30	-	-
Proportion of respondents accepting travel time	14. 3%	28. 6%	57. 1%	100. 0%	-	-
Maximum acceptable travel time to a psychologist (minutes)	100 80	480	300	120	60	-
Proportion of respondents accepting travel time	14. 3%	28. 6%	42. 9%	71.4 %	100. 0%	-
Maximum acceptable travel time to a psychiatrist (minutes)	100 80	480	120	60	30	-
Proportion of respondents accepting travel time	14. 3%	28. 6%	57. 1%	85.7 %	100. 0%	-
Maximum acceptable travel time to a taxi or shuttle depot (minutes)	480	120	60	30	20	15
Proportion of respondents accepting travel time	14. 3%	28. 6%	42. 9%	57.1 %	71.4 %	100. 0%

For all spatial attributes, at least one maximum travel time was the same for two or more respondents, resulting in no spatial attributes with seven thresholds. Five of the eight spatial attributes had five thresholds, two had four thresholds, and one had six.

#### **6.2.1.4.            *Other***

Respondents were also offered the opportunity to suggest other spatial attributes that were relevant to them when deciding where to locate a new facility. These could not be included in this suitability analysis but may be of interest to future studies. Five attributes were suggested, four of which were unique.

Two respondents reported proximity to retirement villages as being highly important (scores of five and six on the sliding scales) when planning locations. Both respondents linked the proximity of these villages to likely demand in the region: the first describing villages as “feeders for referrals” to aged residential care, and the second equating retirement villages with other areas “offering density of older population groupings”. A second respondent also reported proximity to other ARCFs as being reasonably important, assigning it a value of four. The reason for this was not elaborated but is perhaps related to business clustering or economic agglomeration, where like-business cluster to attract suppliers and clients. The final two factors of importance given were more obvious: mobile phone reception (i.e. facility located within a coverage zone) and facility located near to public transport.

#### **6.2.2.            *Weighted linear combination (WLC)***

As explained in the previous chapter, data availability and reliability issues meant that only nine of 15 spatial attributes could be used. The generated attribute maps for each of the spatial attribute are shown below.

Figure 17: Acceptable travel time from an emergency department by number of respondents

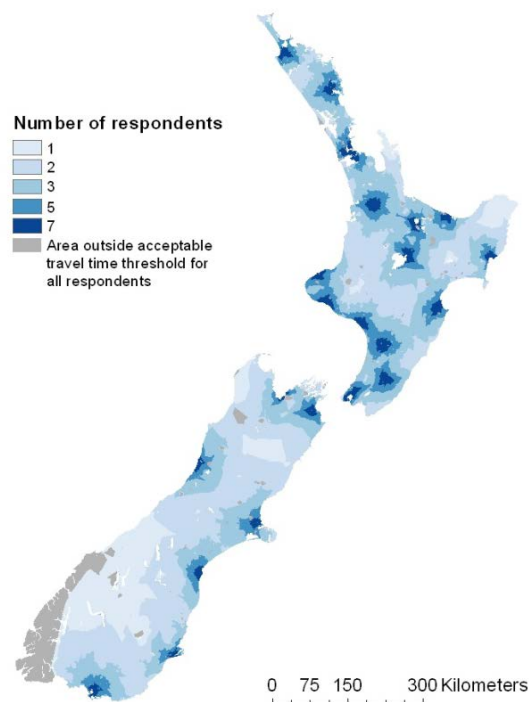


Figure 19: Acceptable travel time from a public hospital by number of respondents

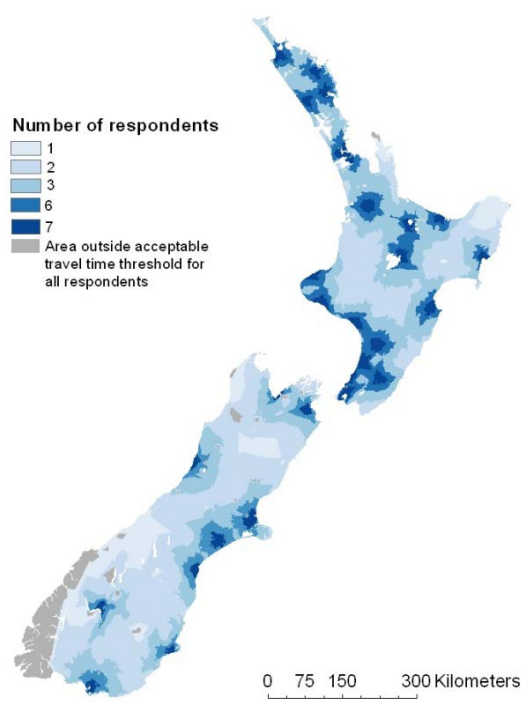


Figure 18: Acceptable travel time from a fire station by number of respondents

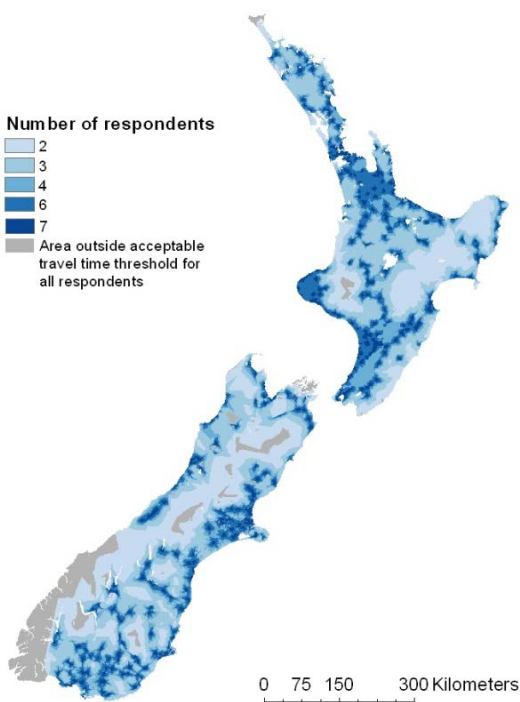


Figure 20: Acceptable travel time from a dentist by number of respondents

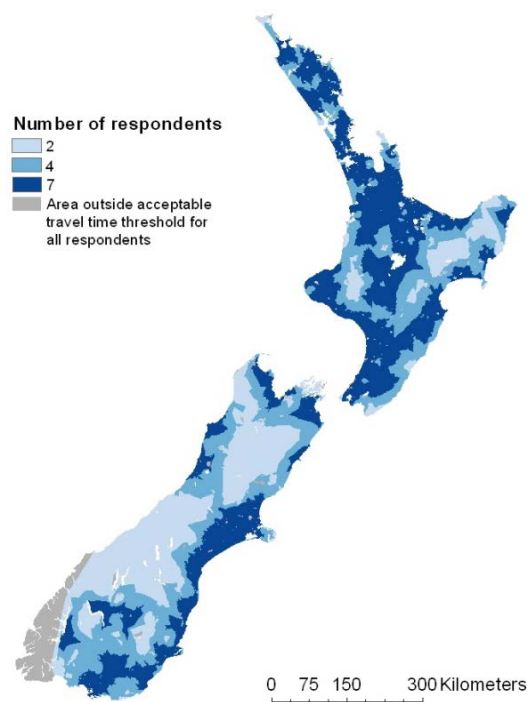




Figure 21: Acceptable travel time from a GP by number of respondents

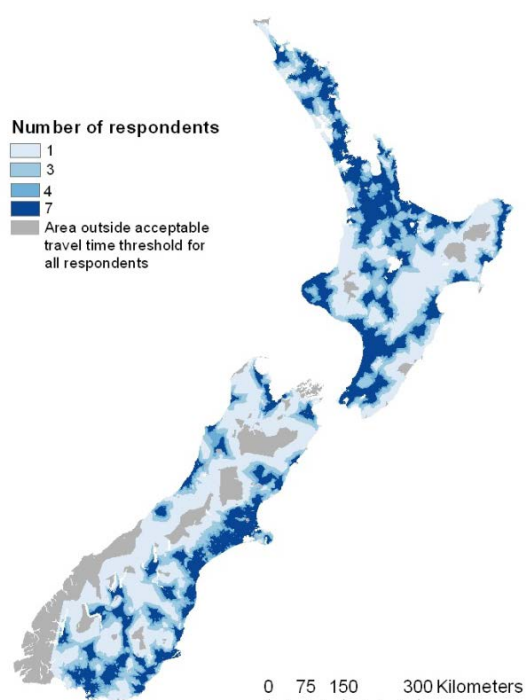


Figure 23: Area currently served by access road



Figure 22: Acceptable travel time from a psychiatrist by number of respondents

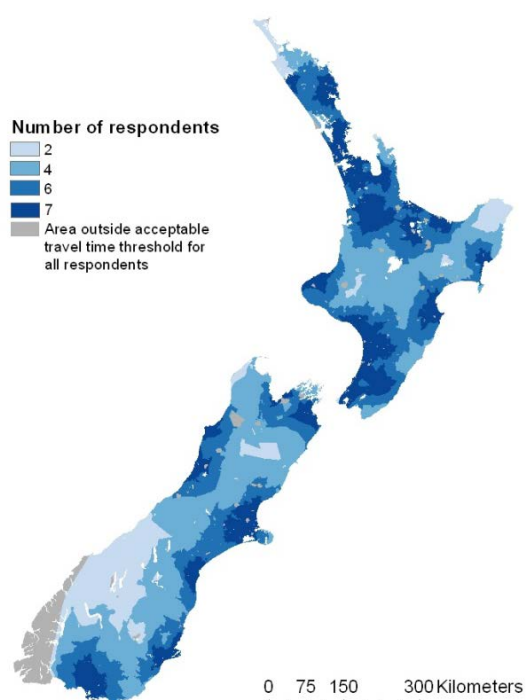


Figure 24: Area currently served by electricity distribution lines

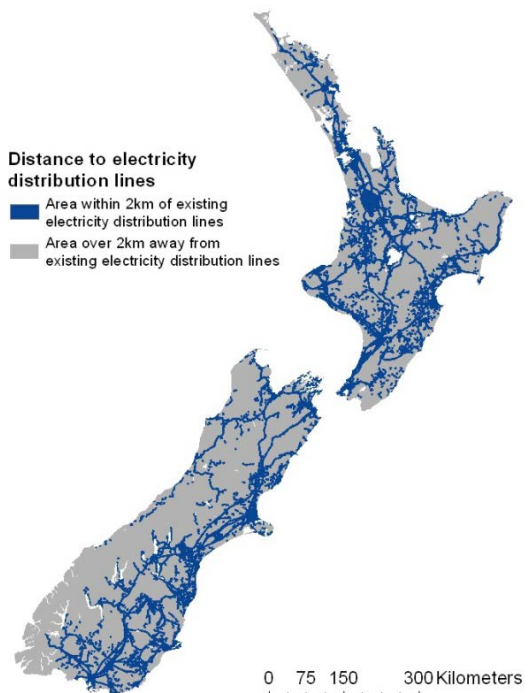
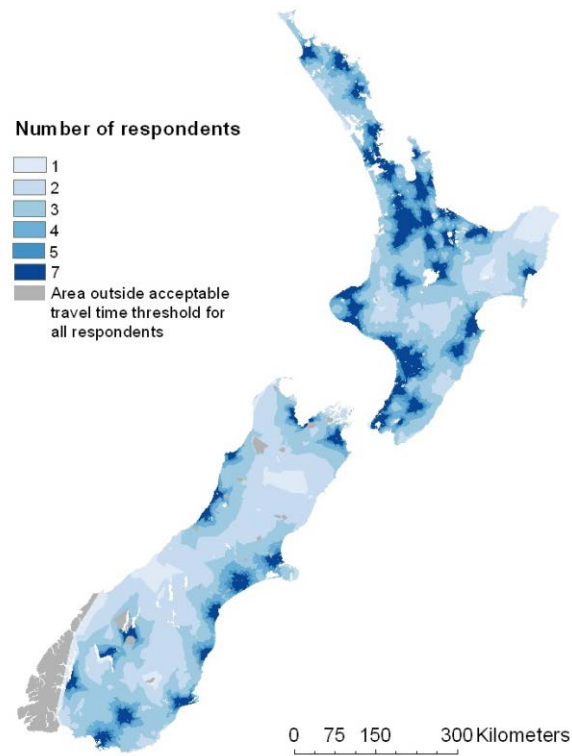
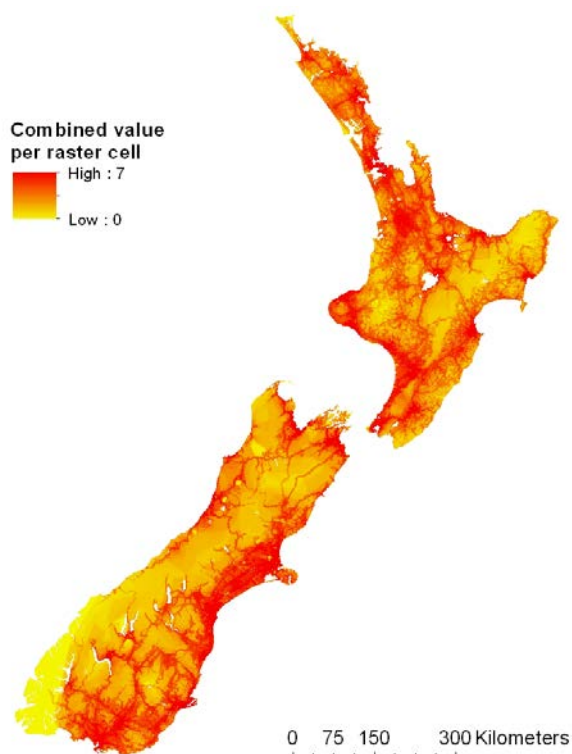


Figure 25: Acceptable travel time from a taxi or shuttle depot by number of respondents



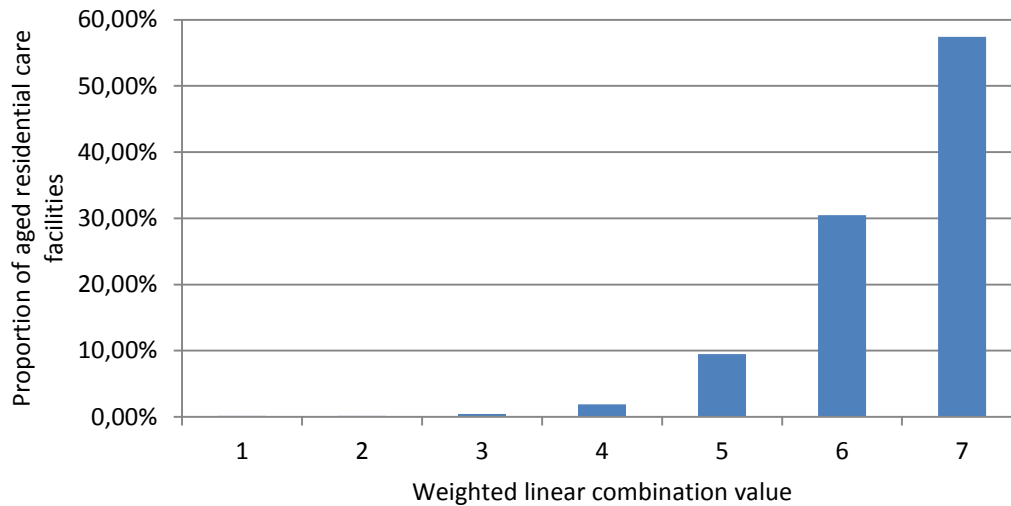
These individual spatial attribute maps were combined together using a WLC to develop a 'surface of acceptability' for the whole country (Figure 26).

Figure 26: WLC of all nine spatial attributes



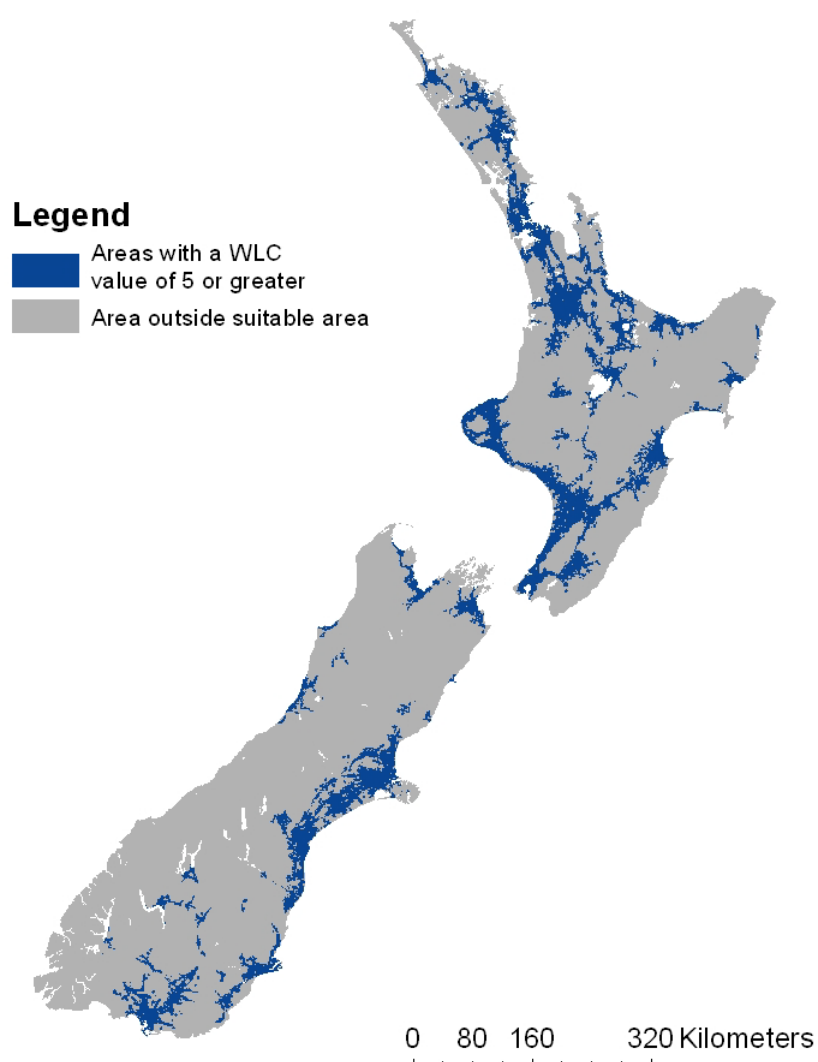
For every parcel of land in mainland New Zealand (North and South Islands) a value between 0 and 7 was returned. Parcels with a value of 0 were unacceptable to every respondent for at least one attribute and parcels with a value of seven were acceptable to every respondent for every category. A value in-between meant location was acceptable to at least one respondent in each category. As explained in section 4.2.6, the acceptability values at current ARCF locations were then used as a proxy for maximum acceptable compromise.

Figure 27: Proportion of existing aged residential facilities by WLC value



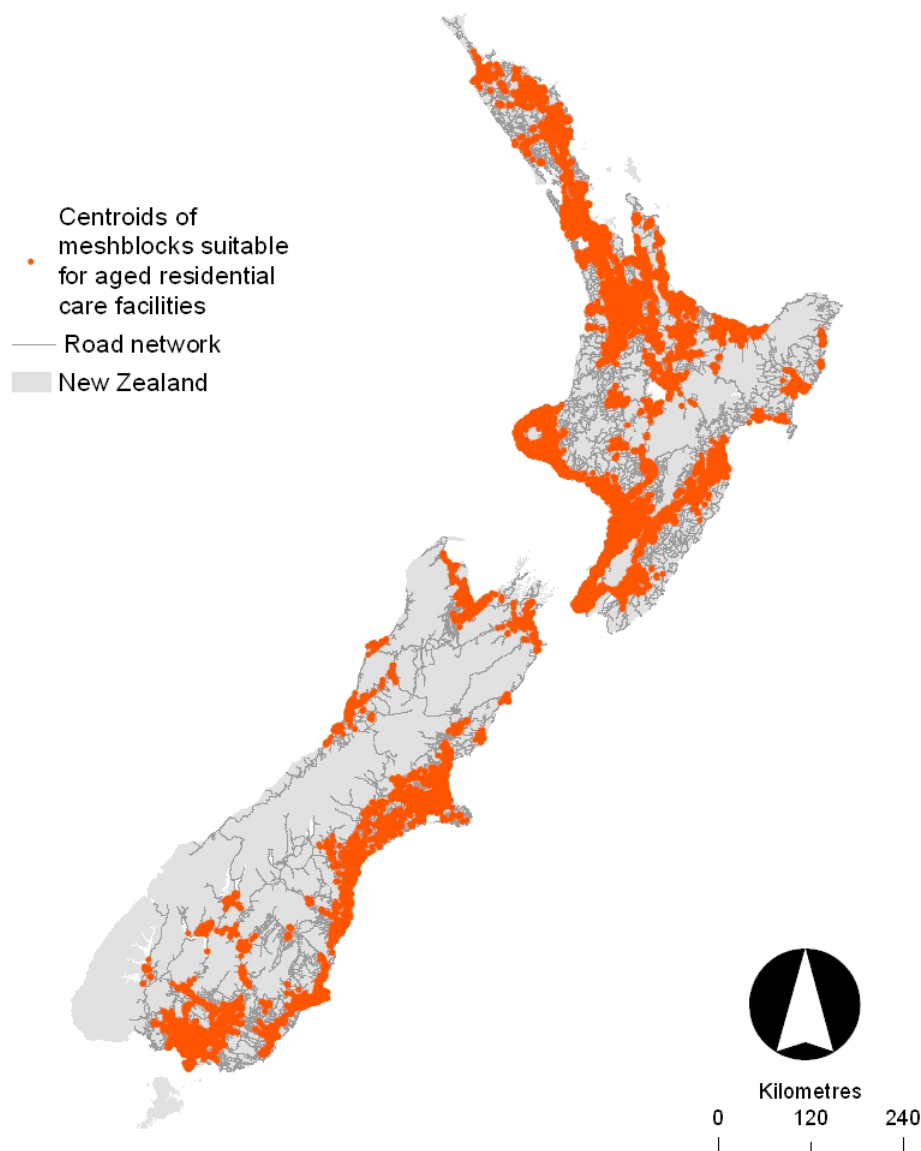
The majority of facilities were located within areas with a WLC value of seven (57%). A further 30% were located in areas with a value of six, and 9% within areas with a value of five. As over 95% of the ARCFs were located within the top three values the minimum acceptability value was set at five, and parcels with WLC values of 5 or greater were taken as being acceptable. The acceptable regions were exported into a new map (Figure 28).

Figure 28: Potentially suitable areas (WLC score of 5 or greater)



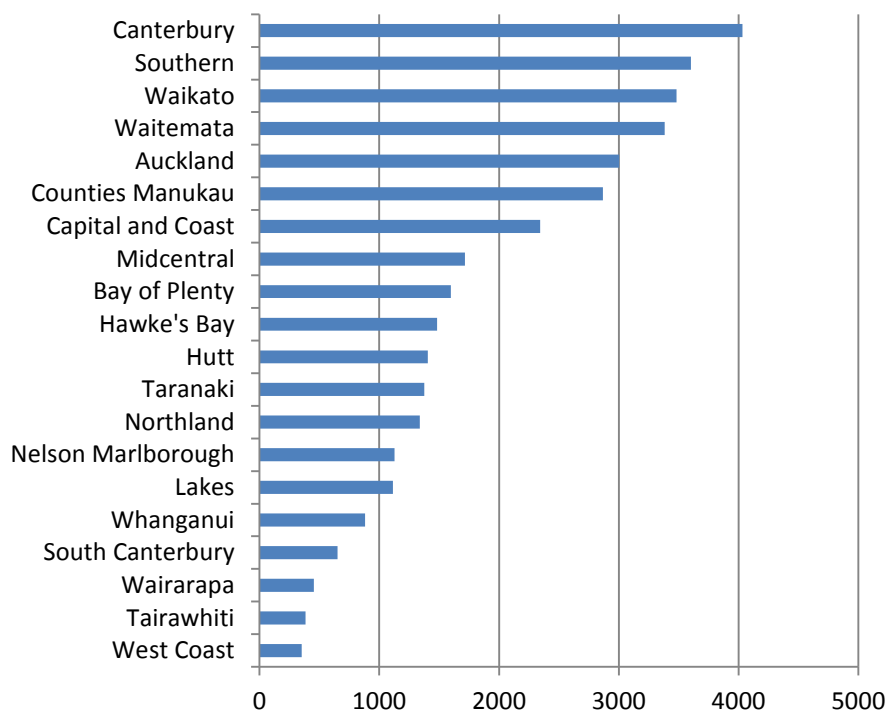
The centroids of meshblocks containing potentially suitable land areas of sufficient size for an ARCF were then exported to a new map (Figure 29). These point locations represent the potentially suitable meshblocks within which to place an ARCF. Detailed maps of potential locations by DHB can be found in Appendix five and show local spatial variation which is obscured at this scale.

Figure 29: Centroids of potentially suitable meshblocks



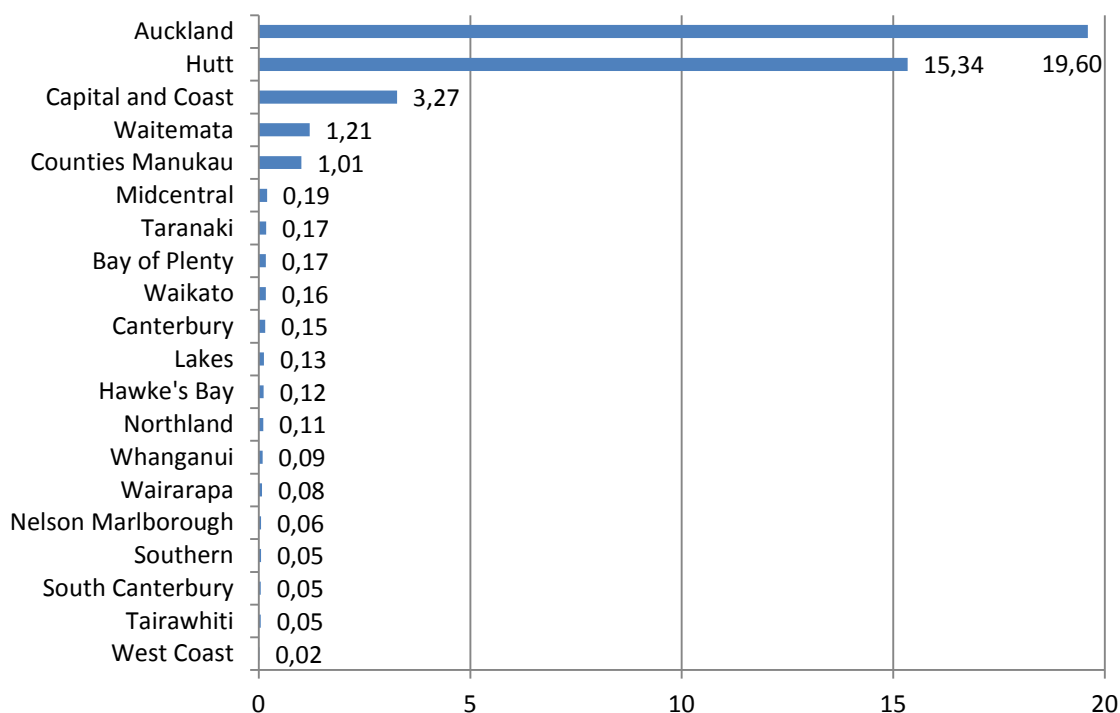
From a visual observation it can be seen that potential locations are not evenly distributed across the country. Large areas of the centre and the west and south coasts of the South Island, the east coast of the North Island have very few potential locations. Large pockets without potential locations can also be seen in the central North Island. Thick clusters of potential locations are found throughout Southland and Canterbury, Greater Wellington, parts of Taranaki and Manawatu, around Hamilton and up through Auckland. The number of potential locations by DHB is shown below (Figure 30).

Figure 30: Number of potential locations by DHB



The number of potential locations by DHB reflects the observed clusters. Over 3000 potential locations were generated in Canterbury, Southern, Waikato and Waitemata. While in Wairarapa, Tairāwhiti and the West Coast there were less than 500. When compared against land area however, the results were quite different (Figure 31).

Figure 31: Potential locations per square kilometre by DHB



The urban DHBs had a far higher number of potential locations per square kilometre than the rural DHBs. Canterbury, Southern and Waikato despite having the largest number of total locations had less than 0.2 locations per square kilometre. Auckland and Hutt on the other hand had values over 15. It might be expected that in the DHB with fewer potential locations per kilometre, chosen locations will be more of a compromise and accessibility may be less equitable.

### **6.2.3. Summary**

Spatial attributes pertaining to the presence of utilities were the most important attributes for providers when deciding where to place an ARCF. With the exception of distance from a natural gas pipeline all decision makers assigned high importance to all the utilities. Travel time to a GP was the most important of the health-related spatial attributes. Access to the other associated health services were the least important by some margin.

The potential location generated from the decision makers' spatial preferences were typically clustered around centres of settlement, typically larger towns and cities. This meant there were comparatively few potential locations in some of the more rural DHBs. This also meant that the potential number of locations by square kilometre was very high in the smaller, more urban DHBs and the larger, more rural DHBs had much fewer locations per square kilometre. It is important to highlight that only seven providers responded in full to the survey and those that did were predominantly not-for-profit. This low sample size may mean these results are over- or under- estimated.

## **6.3. Part 3: Choosing optimal locations**

This section presents the results of the location-allocation analysis to select the most optimal locations for ARCFs given the distribution of the population. Two separate location-allocation scenarios were modelled: Scenario A (52,291 beds required in 2026) and Scenario B (44,129 beds required in 2026).

### **6.3.1. Future demand and required supply**

An estimate of the demand, the number of required facilities, and the required number of beds per facility was calculated for each DHB and each scenario (Table 16).



Table 16: Future demand and required supply by DHB

	Total facilities (2011)	Existing 65+ bed facilities (2011)	Number of users (2026)		Required facilities (2026)		Beds required per facility (2026)		New facilities required (2026)		Difference (2011-2026)	
			Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
District Health Board												
Auckland	77	20	5,692	4,802	71	60	81	81	51	40	-6	-17
Bay of Plenty	31	7	2,588	2,190	32	27	81	82	25	20	1	-4
Canterbury	91	30	6,061	5,110	75	63	81	82	45	33	-16	-28
Capital and Coast	34	11	3,512	2,958	43	36	82	83	32	25	9	2
Counties Manukau	40	15	6,645	5,603	83	70	81	81	68	55	43	30
Hawke's Bay	28	7	1,664	1,403	20	17	84	83	13	10	-8	-11
Hutt	16	9	1,542	1,301	19	16	82	82	10	7	3	0
Lakes	13	5	1,109	932	13	11	86	85	8	6	0	-2
Midcentral	38	2	1,882	1,588	23	19	82	84	21	17	-15	-19
Nelson Marlborough	24	6	1,570	1,328	19	16	83	84	13	10	-5	-8
Northland	23	6	1,785	1,497	22	18	82	84	16	12	-1	-5
South Canterbury	13	3	586	496	7	6	84	83	4	3	-6	-7
Southern	70	14	3,290	2,773	41	34	81	82	27	20	-29	-36
Tairāwhiti	7	3	487	410	6	5	82	82	3	2	-1	-2
Taranaki	31	6	1,153	973	14	12	83	82	8	6	-17	-19
Waikato	53	10	4,217	3,552	52	44	82	81	42	34	-1	-9
Wairarapa	12	1	421	353	5	4	85	89	4	3	-7	-8
Waitemata	58	15	6,970	5,884	87	73	81	81	72	58	29	15
West Coast	5	1	334	284	4	3	84	95	3	2	-1	-2
Whanganui	15	2	623	524	7	6	89	88	5	4	-8	-9
Total	679	173	52,131	43,961	643	540	-	-	470	367	-36	-139

The number of expected users per DHB ranged from 334 in West Coast DHB to 6970 in Waitemata DHB under Scenario A and 284 to 5884 under Scenario B. Subsequently, the required number of facilities for both scenarios was lowest in West Coast at 4 and 3 and highest in Waitemata at 87 and 73. The slightly lower total number of users is a product of the process to identify likely demand at the area unit (see section 4.3.1).

Facilities in most DHBs in both scenarios required between 81 and 83 beds to serve the number of expected user. However, in four of the least populous DHBs (Lakes, Wairarapa, West Coast and Whanganui) facilities had to be significantly larger to accommodate the number of expected users while maintaining a minimum operating efficiency of 80 beds or more.

All DHBs had at least one existing 65+ bed facility. Canterbury had the most at 30 followed by Auckland at 20. Wairarapa and West Coast both had just one existing facility of sufficient size. Most DHB in both scenarios required more than ten facilities. Waitemata had the highest need at 72 and 58 facilities, followed closely by Counties Manukau at 68 and 55. Tairāwhiti and West Coast required the fewest facilities at 3 and 2, followed by South Canterbury and Wairarapa at 4 and 5. Only Tairāwhiti had existing facilities that made up more than half the required number of facilities.

Overall, the total number of required facilities was fewer in 2026 under both scenarios than in 2011, with Scenario A down by 36 beds and Scenario B by 139. 14 DHB had fewer facilities in 2026 under both scenarios. Southern had the biggest reduction, down by 29 and 36 in scenarios A and B respectively. Three scenarios had an increase in the number of DHBs in both scenarios, most notably Waitemata with an additional 29 and 15 facilities.

### **6.3.2. Chosen locations**

Once the number of required facilities and their respective sizes were identified the location-allocation analysis was run twice for each DHB – once per scenario. The locations generated by these analyses are mapped by scenario below. More detailed maps by DHB can be found in Appendix five.

Figure 32: Chosen facility locations, Scenario A

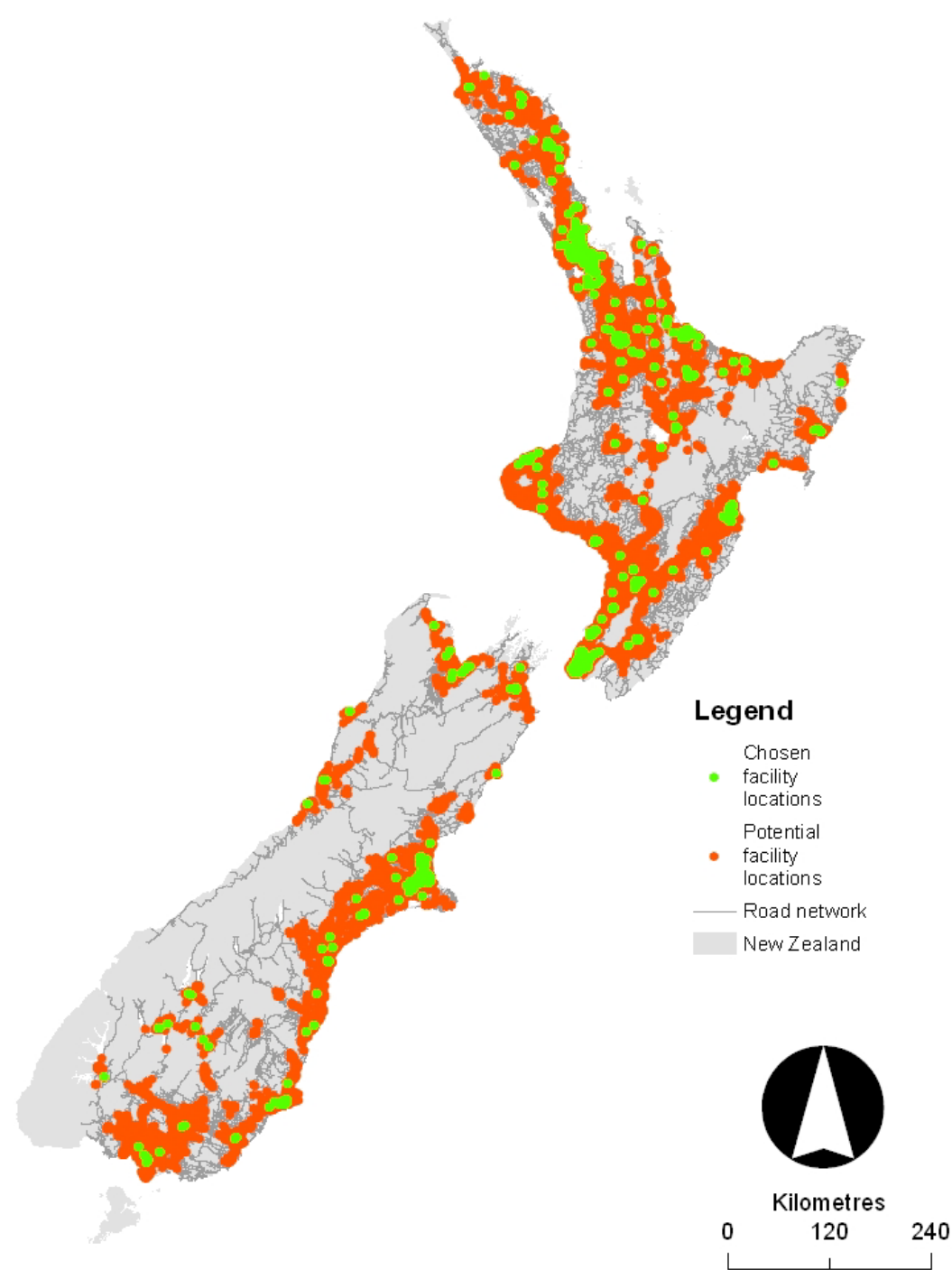
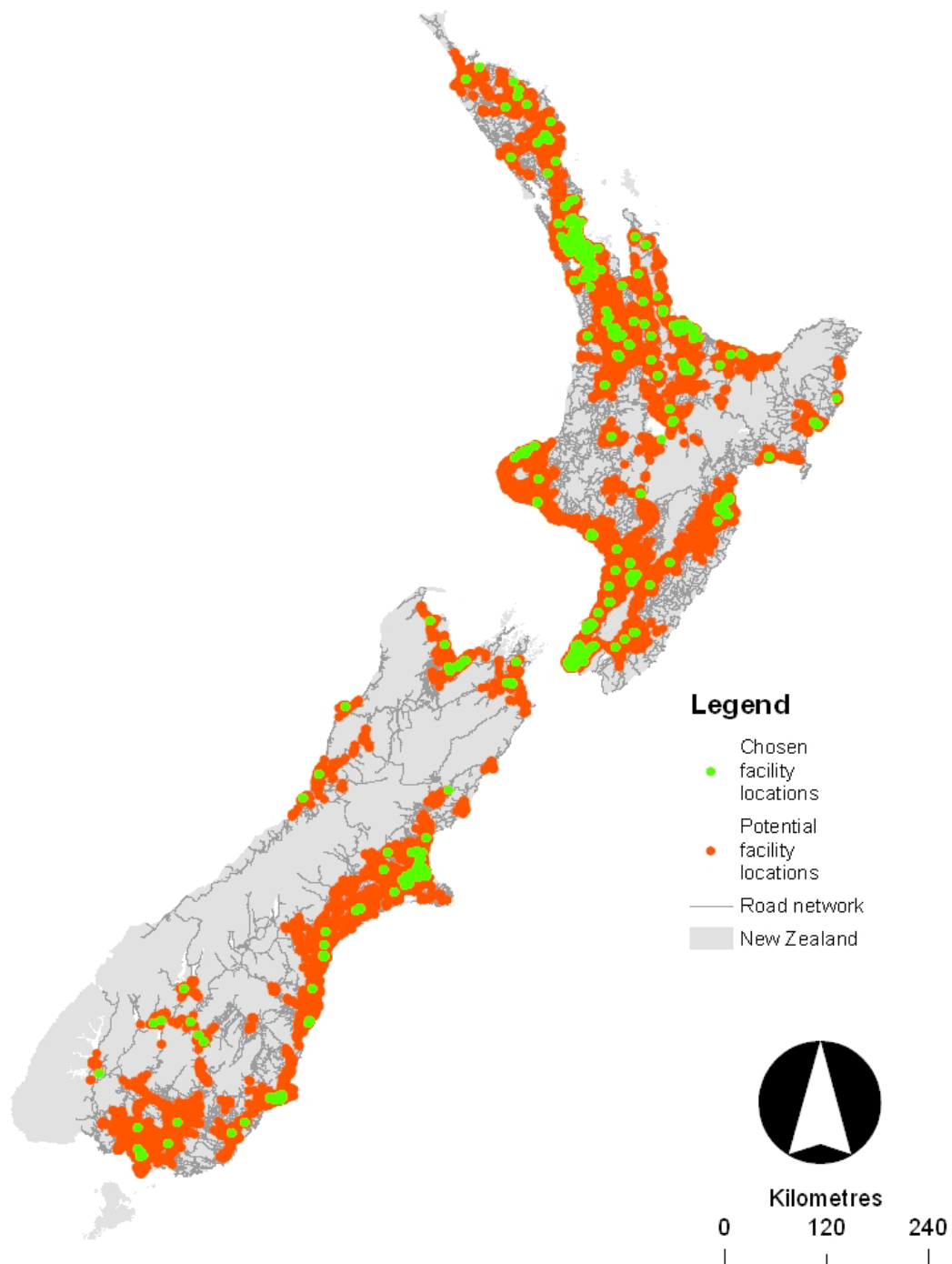


Figure 33: Chosen facility locations, Scenario B

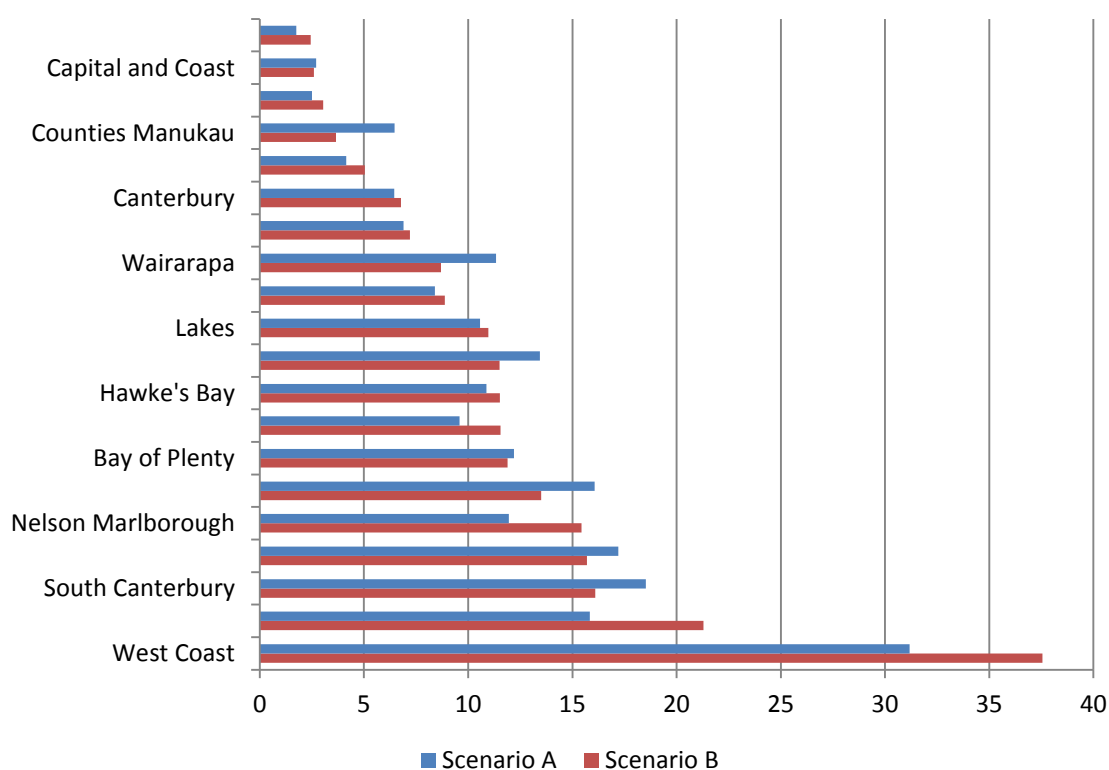


From a visual observation it appears that chosen locations are fairly evenly distributed between the potential locations. Significant clustering can be seen in both scenarios around the major urban centres.

### 6.3.3. Travel time to allocated facility

The resultant travel times from each population point to each allocated facility are summarised by DHB and scenario below (Figure 34). See Appendix six for the complete summary of travel times by DHB.

Figure 34: Mean travel time to allocated facility by DHB and Scenario



In both scenarios, most journeys are very short: less than three minutes in optimal conditions. This is achieved by many facilities being located very near the population centroids. The stated time must be treated with caution as actual population distribution within an area unit is obviously much more disparate than a centroid allows.

In scenario A, the mean travel time was just over ten minutes. There was sizeable variation between DHBs. As might be expected with the population density, the smaller, predominantly urban DHBs tended to have lower travel times, whilst larger, predominantly rural DHBs had the highest. Auckland DHB had the lowest mean at just 1.8 minutes. Hutt and Capital and Coast followed each with less than three minutes. West Coast DHB had the highest mean travel time at nearly 32 minutes, considerably higher than the next highest travel times of South Canterbury (18.5 minutes) and Southern (17.2 minutes).

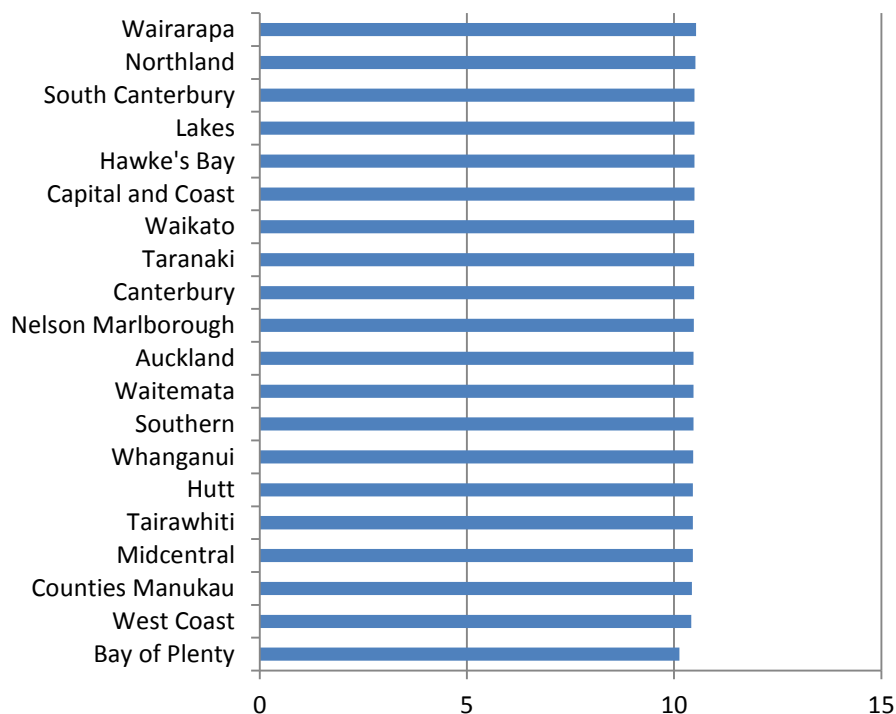
In scenario B, the mean travel time was just under ten minutes. Like with scenario A, there was considerable variation between the DHBs. Auckland DHB again had the shortest mean travel

time of 2.4 minutes, up slightly from scenario A. Capital and Coast DHB was next on 2.6 minutes followed closely by Hutt DHB on 3.0. West Coast DHB again had the highest mean travel time (38 minutes). Tairāwhiti followed next on 21 minutes, then South Canterbury and Southern both around 16 minutes, and Nelson Marlborough on 15 minutes.

#### 6.3.4. Bed-to-population rate

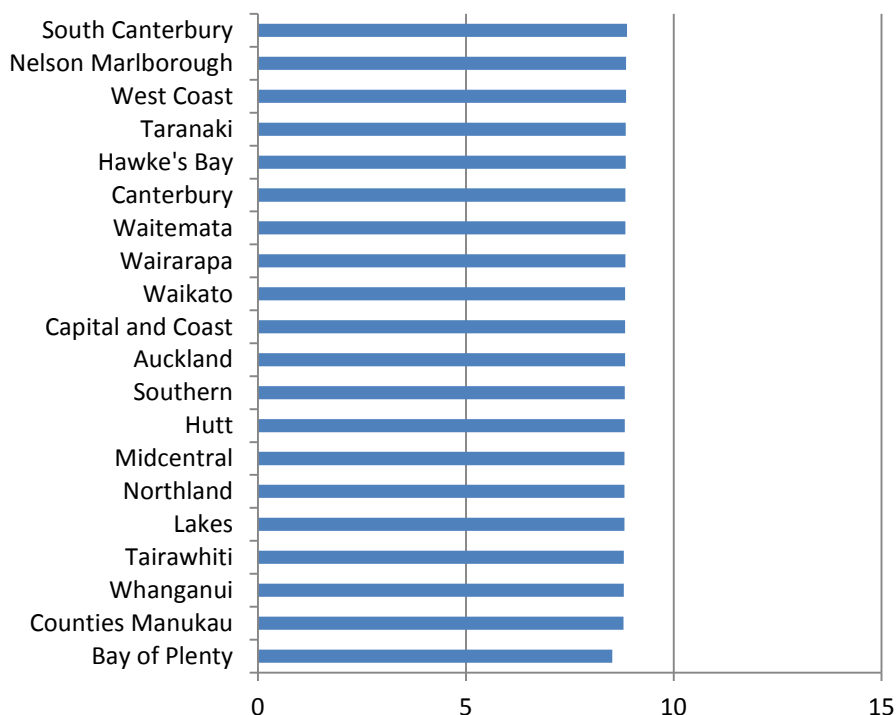
To compare the spatial accessibility of the chosen facility locations in Scenarios A and B against the spatial accessibility of facility locations in 2011, the bed-to-population ratios from Part 1 were replicated for each Scenario. Firstly, the bed-to-population rate was calculated by DHB (Figure 35 and Figure 36).

Figure 35: ARCF beds per 1000 people, by DHB. Scenario A



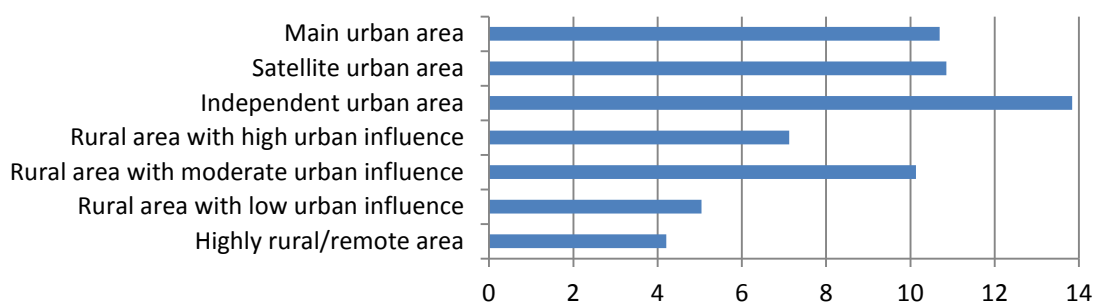
Very similar ratios were returned for all DHBs, contrasting markedly with the large variation observed in 2011. This uniformity was the result of future bed numbers being assigned to the analysis based on population of the DHB. In Scenario A, the national bed-to-population rate was 10.5 and all DHBs returned values between 10 and 11.

Figure 36: ARCF beds per 1000 people, by DHB. Scenario B



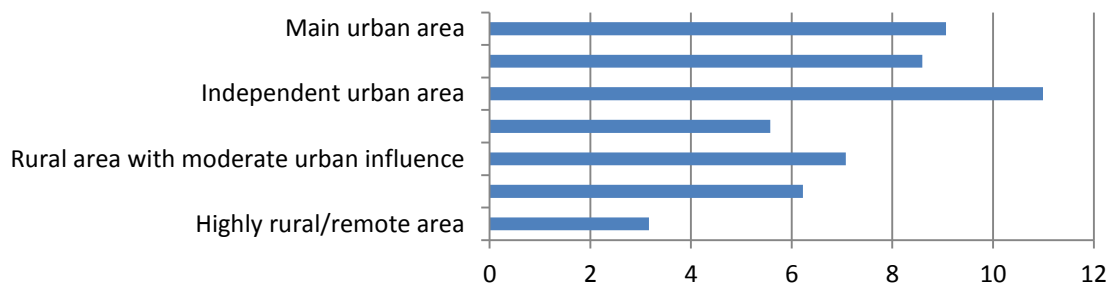
In Scenario B, the assigned lower demand resulted in lower overall bed-to-population ratios. The national rate for Scenario B was 8.8 and all DHBs returned values between 8.5 and 8.9. However, when split by urban/rural category, substantial variation remained.

Figure 37: ARCF beds per 1000 people, by urban/rural category. Scenario A



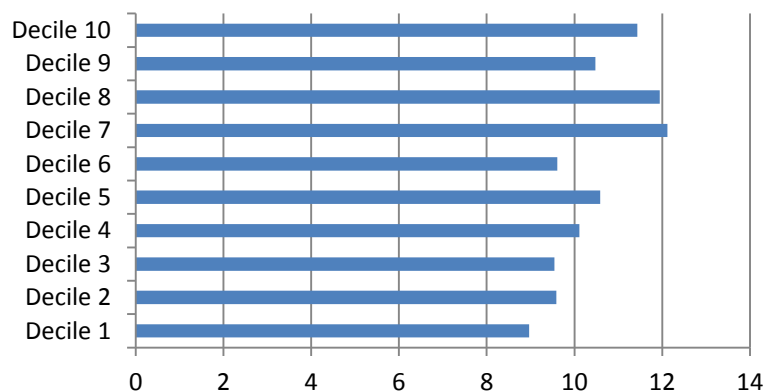
In 2011, each of the urban categories exceeded the national rate and each of the rural categories scored significantly less (see Figure 9). In Scenario A, this remains true (Figure 37). but where all rural areas were below 30% of the national rate in 2011, all were above 40% in Scenario A. Rural areas with moderate urban influence were had a rate 97% of the national rate and Rural areas with high urban influence had a rate 68% of the national rate. Again, independent urban areas were the most over-supplied with beds and Highly rural/ remote areas the most under-supplied. For Scenario B, the results were similar (Figure 38).

Figure 38: ARCF beds per 1000 people, by urban/rural category. Scenario B



Urban areas were consistently higher than rural areas, yet satellite urban areas scored very slightly below the national average of 8.8. All rural areas were 35% of the national average or more, a significant improvement on 2011 yet short of the 40% in Scenario A. Like Scenario A, rural areas with moderate urban influence was the highest scoring of these at 80% of the national average. Interestingly, rural areas with low urban influence scored higher than those with high urban influence. The variation by deprivation decile was considerably more muted than in 2011 (Figure 39).

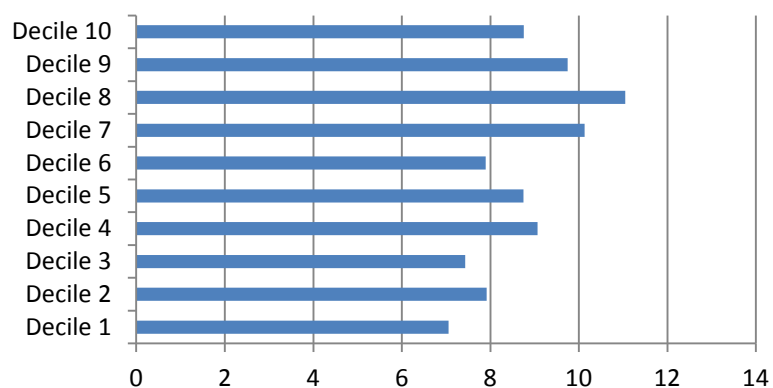
Figure 39: ARCF beds per 1000 people by deprivation decile. Scenario A



In 2011, decile bed-to-population ratios varied from 65% to 135% of the national rate (see Figure 10). In Scenario A ratios varied from 86% to 116% of the national rate, approximately 20 percentage points in each direction. Interestingly, areas with higher dependency tended to have higher ratios than low dependency areas, although the difference was small.



Figure 40: ARCF beds per 1000 people by deprivation decile. Scenario B



Scenario B also showed reduced variation from 2011 levels. Ratios varied from 7.1 to 11.0 or 80% to 125% of the national rate, still substantially less than in 2011. As with Scenario A there was a recognisable split between lower and higher decile regions, with more beds per population in more deprived areas.

#### 6.3.5. Travel time to nearest facility

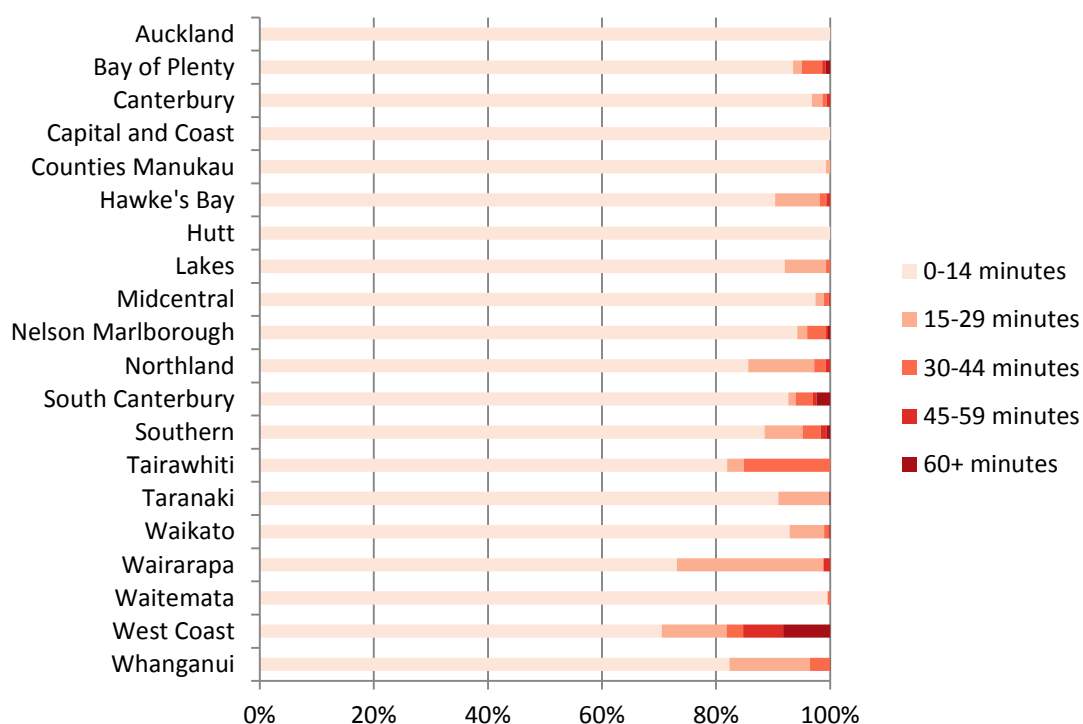
Travel time to closest facility was also calculated for each area unit to allow comparison with the data from 2011 (see section 6.1.2). Firstly, mean travel time to nearest facility was calculated for each DHB (Table 17).

**Table 17: Mean travel time (minutes) to nearest facility by DHB and scenario**

DHB	2011	2026	
		A	B
Auckland	1.91	1.07	1.37
Bay of Plenty	8.05	8.69	9.22
Canterbury	6.19	5.60	5.99
Capital and Coast	2.61	1.62	1.78
Counties Manukau	4.20	2.18	2.47
Hawke's Bay	8.77	8.31	8.44
Hutt	3.06	1.97	2.18
Lakes	10.13	7.44	7.95
Midcentral	6.98	6.28	6.44
Nelson Marlborough	11.23	9.54	9.65
Northland	11.08	10.26	10.18
South Canterbury	17.22	15.90	16.49
Southern	11.49	12.50	12.87
Tairāwhiti	26.27	10.45	13.94
Taranaki	6.28	7.80	8.36
Waikato	7.60	7.25	7.55
Wairarapa	6.34	9.53	7.51
Waitemata	4.85	3.14	3.47
West Coast	35.75	32.29	33.22
Whanganui	15.20	8.56	8.72
<b>Total</b>	<b>8.47</b>	<b>7.42</b>	<b>7.75</b>

Mean travel times were generally lower than in 2011 in both scenarios. The national mean travel time was 8.5 minutes in 2011. In Scenario A, this fell 12% to 7.4 minutes and under Scenario B it fell 8% to 7.8 minutes. Travel times in both scenarios were lower than 2011 levels in 16 of the 20 DHB. Tairāwhiti recorded the greatest reduction in mean travel time under Scenario A to 10.5 minutes from 26.2 minutes in 2011, a reduction of over 60%. However, mean travel times in Bay of Plenty, Southern, Taranaki and Wairarapa DHBs were higher than in 2011. Wairarapa had the largest increase at 3.2 minutes under Scenario A, taking travel time to 9.5 minutes, 50% higher than the 6.3 minutes in 2011. The proportion of population by travel time to closest facility by DHB was calculated for scenario A (Figure 41) and scenario B (Figure 42).

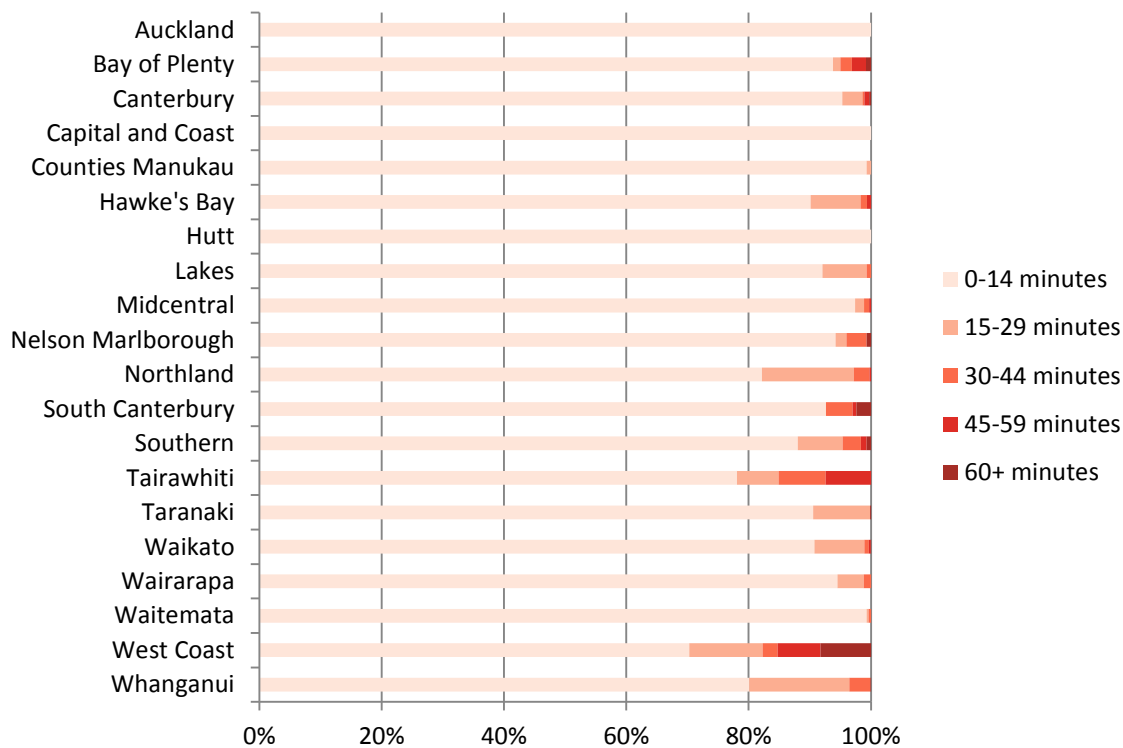
Figure 41: Proportion of population by travel time to closest ARCF (minutes) and DHB, Scenario A



Despite the overall lower number of facilities, the spread was remarkably similar between that in 2011 (Figure 13) and the projected in 2026 under Scenario A. In smaller, more urban DHBs where travel time to closest facility was less than thirty minutes for all area units in 2011, travel time was largely unchanged. In some of the larger, more rural DHBs however travel time was reduced under Scenario A. In Whanganui DHB the proportion of the population less than 30 minutes from a facility increased from 85% to 96%, and the proportion over an hour fell from 7% to zero. Similarly in Tairāwhiti DHB, the population less than 30 minutes from a facility rose from 82% to 85%, and the population over an hour decreased to zero from over 10%.

In most DHBs, the proportion of the population with travel time under 15 minutes increased under scenario A. In seven of the 20 DHBs travel time over an hour increased under Scenario A, compared with five of the twenty decreasing under Scenario A. However, none of the increases exceed 1.5 percent, while two of the decreases exceed 5%.

Figure 42: Proportion of population by travel time to closest ARCF (minutes) and DHB, Scenario B



Similar results were also observed under Scenario B. Auckland, Capital and Coast and Hutt all returned 100% of travel times to closest facility of less than fifteen minutes. As with Scenario A, substantial improvements in spatial access occurred in Whanganui DHB where the proportion of the population less than 30 minutes from a facility increased from 85% to 96% and the proportion over an hour fell from 7% to less than 1%, and in Tairāwhiti DHB where the proportion under 30 minutes from a facility rose from 82% to 85%, and the proportion over an hour fell from over 10% to zero. In West Coast DHB, the proportion less than 15 minutes from a facility increases from 53% to 70%. When comparing the proportion of population less than 30 minutes from a facility between 2011 data and each of the 2026 scenarios, the small improvements are clear (Table 18).

Table 18: Proportion of population under 30 minutes from nearest facility

DHB	2011	2026	
		Scenario A	Scenario B
Auckland	100.00%	100.00%	100.00%
Bay of Plenty	97.50%	94.99%	94.99%
Canterbury	98.48%	98.64%	98.60%
Capital and Coast	100.00%	100.00%	100.00%
Counties Manukau	100.00%	100.00%	100.00%
Hawke's Bay	98.61%	98.15%	98.29%
Hutt	100.00%	100.00%	100.00%
Lakes	97.53%	99.30%	99.30%
Midcentral	98.81%	98.87%	98.87%
Nelson Marlborough	92.30%	95.99%	95.99%
Northland	96.98%	97.21%	97.21%
South Canterbury	92.76%	93.94%	92.64%
Southern	95.77%	95.19%	95.36%
Tairāwhiti	81.80%	84.88%	84.88%
Taranaki	99.85%	99.86%	99.86%
Waikato	99.04%	98.94%	98.94%
Wairarapa	98.86%	98.83%	98.83%
Waitemata	99.90%	99.59%	99.59%
West Coast	65.33%	81.83%	82.30%
Whanganui	84.54%	96.49%	96.49%
<b>Total</b>	<b>98.03%</b>	<b>98.40%</b>	<b>98.40%</b>

Overall, proportion of travel time under 30 minutes from a facility increased slightly, from 98.0% in 2011 to 98.4% in both scenarios. Proportions increased under both scenarios in nine of 20 DHBs, stayed the same (at 100%) in four, and increased under at least one scenario in the remaining seven. Some DHB displayed substantial improvement. The proportion under 30 minutes increased by 17 percentage points in West Coast DHB in both scenarios, and Whanganui by 12. Decreases were generally small, with none exceeding 2.5 percentage points. The travel time to nearest facility results were also analysed by urban/rural category for Scenario A (Figure 43) and Scenario B (Figure 44).

Figure 43: Proportion of population by travel time to closest ARCF (minutes) and urban/rural profile, Scenario A

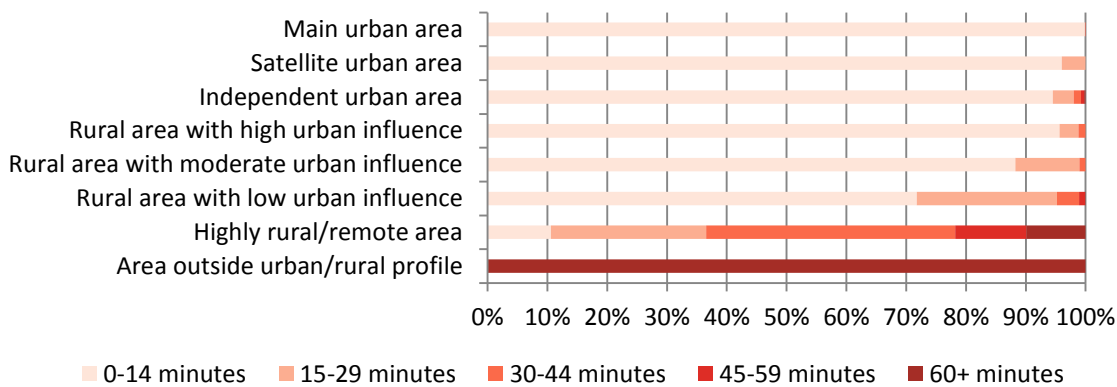
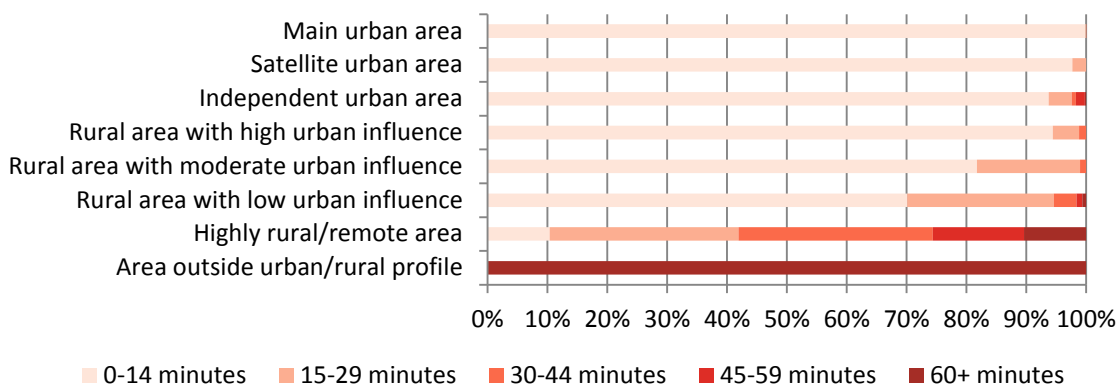


Figure 44: Proportion of population by travel time to closest ARCF (minutes) and urban/rural profile, Scenario B



As with the proportion of population by travel time and DHB, the general spread of the data was very similar to the results from 2011 (refer Figure 14). More urban areas had lower travel times than more rural areas, with the exception of Independent urban areas which had slightly higher travel times than rural areas with high urban influence. A greater proportion of the population was located within 15 minutes for all categories except highly rural/remote areas, which increased by 8% in both scenarios and areas outside urban/rural profile which remained the same. Rural areas with moderate urban influence had the highest increase at 23%. Proportion over an hour remained the same or fell in all categories in both scenarios. However, the proportion under half an hour decreased in both scenarios for highly rural/remote areas, rural areas with moderate urban influence and rural areas with high urban influence.

#### 6.3.6. Summary

With the requirement of at least 80 beds per facility considerably fewer facilities would be needed in 2026 than were operating in 2011. Facility numbers decreased in both scenarios in 15 of 20 DHBs.

Mean travel times to nearest facility were lower overall in both scenarios compared to 2011, and were lower in most DHB. Several DHB recorded large improvements. Whanganui, Waitemata, Tairāwhiti, Lakes, Hutt, Counties Manukau, Capital and Coast, and Auckland all had travel time reductions of over 25%. However, not all DHB registered improvements. Bay of Plenty, Southern, Taranaki and Wairarapa all recorded increases in average travel time. A similar regress was seen with the proportion of population under 30 minutes decreasing for each of these DHBs. With the exception of Bay of Plenty each of these DHB previously had provider to population ratios above the national average, and each were allocated considerably fewer facilities than 2011 in both scenarios.

Variation between urban/rural category was also slightly reduced. More urban areas still had lower travel times than more rural areas, but a greater proportion of the population was located within 15 minutes for all categories except for highly rural remote areas which decreased in both scenarios and areas outside urban/rural profile which remain the same. Variation was also reduced in bed-to-population ratios.





## 7. Discussion

This research set out to answer the research question: *to what extent can geographic information science (GIS) methods be used to assess current and identify and assess potential future locations of aged residential care facilities in New Zealand?* To help answer this central research question, four sub questions were identified:

1. *What can GIS methods show us about the equity of the locations of aged residential care facilities in New Zealand?*
2. *How can GIS methods identify potential future locations that are suitable to providers for the placement of aged residential care facilities and where are these locations for New Zealand?*
3. *How can GIS methods identify, from the potential future locations, those that most optimally supply the population, and where are these locations for New Zealand given future demand projections?*
4. *Can GIS methods help to improve the equity of the distribution of locations of aged residential care facilities in New Zealand?*

To answer these questions in the specific context of aged residential care in New Zealand currently and in the near future, three objectives were identified that correlated with the four research questions. The results of each of these three objectives are discussed below.

### 7.1.1. Objective one: Measuring current spatial access

This work sought to describe and measure the current accessibility of ARCFs in New Zealand. As was identified in chapter one, evidence of poor spatial access has been mounting in New Zealand for some time (New Zealand Labour et al., 2010; Rural Women New Zealand, 2010; Taylor, 2011). Joseph and Chalmers (1996) showed that the privatisation of ARCFs in Waikato was associated with an increase in the number of beds in urban areas and a decrease in the number in rural areas. Chapter two identified three categories across which variation in spatial access to health services had been observed in other studies in New Zealand: DHBs, urban/rural category and deprivation deciles. Objective one addresses the first sub-research question: *What can GIS methods show us about the equity of the locations of aged residential care facilities in New Zealand?*

The methodology identified two primary categories of GIS-based methods for measuring spatial access to health services: area-based measures, which describe for pre-defined areas the ratio of population need to services available, and impedance-based measures, which describe the impedance between the population and health care services. Within these two

categories, several principal methods were identified and the advantages and disadvantages of each method were summarised in Table 1. A combination of bed-to-population ratios and travel impedance to nearest provider were identified as the most acceptable to this study.

In chapter six, the equity was examined over the three identified categories. Considerable variation in spatial access was found across DHBs. Investigating provider to population ratios highlighted high inequities in the availability of aged residential care, with ratios by DHB varying by up to 50% above and below the national average. Analysing travel time to nearest facility exposed large imbalances in accessibility between DHBs. For example, average travel times to nearest facilities ranged from just two minutes to over 30, and maximum travel times ranged from just five minutes to over three and a half hours. The proportion of the population 30 or more minutes from a facility ranged from zero percent to 35%. West Coast, Whanganui, Tairāwhiti and South Canterbury consistently scored poorly relative to other DHBs, with average travel times and proportion of travel times under 30 minutes in the lowest 25%, and recorded a proportion of their population as being over an hour from the nearest facility. Auckland, Capital and Coast, Counties Manukau and Hutt DHBs on the other hand all scored highly in each of the measures of accessibility.

Substantial variation in spatial access was also seen when compared by urban/rural category. In the bed-to-population ratios, each of the urban categories exceeded the national average and each of the rural categories scored less than a third of the average. When comparing travel time to nearest facility, rural areas had higher travel times than urban areas and for all but satellite urban areas the increases in travel time were shown to be statistically significant. Further, none of the population located in main or satellite urban areas has to travel more than 30 minutes to reach the nearest ARCF. Whereas on highly rural/remote areas, 55% of people have to travel over 30 minutes and 14% have to travel over one hour. In areas outside of the urban/rural profile, the entire population have to travel an hour or more.

The same pattern of high travel times to health facilities in rural, less populous regions of New Zealand was discussed in chapter two. Brabyn and Skelly (2001, 2002) found considerable variation in potential spatial access to public hospitals when aggregated by DHBs, with the large rural DHBs Northland, Tairāwhiti, and Otago and Southland (now merged into Southern) having much higher travel times than other regions. Similarly, Brabyn and Barnett (2004) in their study of potential spatial access to GPs observed that rural areas with low populations had the poorest spatial accessibility.

Variation between deprivation deciles was less pronounced than between DHBs and between urban/rural category. Bed-to-population ratios by decile varied by a third either side of the

national rate, and were lowest in the least deprived and most deprived areas. Average travel times were lowest where deprivation was the highest and where it was the lowest. However the variation was found to generally not be statistically significant and when controlled for urban/rural category none of the variation was found to be statistically significant.

The GIS methods used in this thesis demonstrate clearly that there is considerable variation between areas in the spatial access of ARCFs in New Zealand. Primarily with people in rural areas generally having poorer spatial access than those in urban areas, and people in more rural DHBs typically have poorer spatial access than those in more urban DHBs. However, the results do not appear to show that people in poorer areas have poorer spatial access to ARCFs than people in wealthier areas.

### **7.1.2. Objective two: Identifying potential locations**

Objective two sought to identify areas using GIS methods that are likely to be suitable to providers as potential locations of ARCFs in New Zealand. The second sub-research question is addressed by this objective, specifically: *How can GIS methods identify potential future locations that are suitable to providers for the placement of aged residential care facilities and where are these locations for New Zealand?*

The methodology identified WLC as the most commonly used method and the most appropriate for this study. Subsequently, to achieve the objective three key steps were performed: a review of the literature to identify spatial attributes important to decision-makers when locating new facilities, a survey of providers on the relative importance they assign to each of the attributes when deciding where to locate ARCFs, and a suitability analysis using WLC to aggregate the spatial attributes together by their relative importance to identify areas of potential suitability.

The literature review identified two studies which used GIS methods for selecting locations for ARCFs that were suitable to providers, specifically the State Veterans Associations of Minnesota and Southwest Montana (Engan Associates & Ulteig, 2009; SW Montana Veterans' Home Site Selection Committee, 2009). The spatial attributes identified by these studies were adapted to the New Zealand context and used as the spatial attributes for this study. Providers were then surveyed on the relative importance they assign to these spatial attributes when deciding where to locate an ARCF.

The results of the survey (section 6.2.1) indicated that providers placed the most importance on spatial attributes relating to the practical considerations of locating a facility, primarily the presence of utilities. With the exception of distance from a natural gas pipeline all decision

makers assigned high importance to all the utilities questions. Travel time to a GP was also highly important. Access to the other associated health services were the least important by some margin. When identifying the maximum travel time from the spatial attributes (excluding utilities) that they would feel comfortable placing a facility, respondents again identified GPs as the most important and identified low maximum travel times. Travel time from emergency services and public hospitals too received low travel times, reflecting the importance of time in responding to emergencies. All other attributes were allocated a range of travel times from low to high, perhaps reflecting the lower ratios of use or lower urgency.

The low importance given to the spatial relationships with other health services is interesting. Of the spatial attributes relating to associated health services, travel time to a GP was the most important and had the lowest maximum travel times followed by travel time to hospitals (and emergency departments). All other associated health services were the least important and had the highest maximum travel times. This contrasts with the Veteran's homes with their strong linkages to health services (Engan Associates & Ulteig, 2009). It might be expected that GPs are of high importance to decision makers as they typically act as the gateway into the health system for people in aged residential care and because the age related residential care contract (ARRC) requires facilities to provide GP care to residents. What is of interest is low priority to other associated health services as residents of aged residential care typically have high dependency and restricted mobility and have been shown to rely on family networks to access care for health services outside of the ARRC (Smith, 2010). A result of this might be that access (both spatial and aspatial) to other associated health services may be low. It is important to re-highlight that only seven providers responded in full to the survey and those that did were predominantly not-for-profit. This low sample size may also mean these results are over- or under- estimated.

The resulting potential future locations for ARCFs were generated and mapped in Figure 29. These were typically clustered around centres of settlement, typically larger towns and cities. This meant there were comparatively few potential locations in some of the more rural DHBs. This also meant that the potential number of locations by square kilometre was very high in the smaller, more urban DHBs and the larger, more rural DHBs had much fewer locations per square kilometre.

GIS methods were shown to have been used in other applications to identify potential locations for health services and ARCFs. Methods used in similar applications were identified and evaluated for suitability for use in this study and the use of WLC and a survey of providers was identified as the most appropriate for this application. Centrally, the GIS methods used

(WLC) allows providers' preferences to be included into the spatial decision making process. The results identified that approximately 36,000 of New Zealand's 46,000 meshblocks contained areas thought to be suitable to providers for the location of ARCFs in the future.

### **7.1.3. Objective three: Choosing optimal locations**

The final objective was to determine where the new facilities should go so that spatial accessibility is maximised. This final objective was intended to be used to answer the final two research sub-questions: *How can GIS methods identify from the potential future locations those that most optimally supply the population, and where are these locations for New Zealand given future demand projections and anticipated minimum facility sizes? How can GIS methods help to improve the equity of the distribution of locations of aged residential care facilities in New Zealand?*

The first step was identifying how GIS methods could be used to identify from the potential locations those which would most equitably supply the population. The literature review identified many methods used in non-health applications to identify optimal facility locations and many used to identify optimal locations for health facilities (see Erkut, Ingolfsson, Sim, & Erdoğan, 2009; Şahin et al., 2007; Shariff et al., 2012). However, no applications were identified which sought to locate optimal facilities for ARCFs. The methodology chapter identified location analyses as the category of GIS methods that might be used to for positioning facilities in a given space (ReVelle & Eiselt, 2005). Location-allocation analyses were further identified as the subcategory of location analyses most likely to be suitable for this study. Different location-allocation methods (problem types) were then compared and capacitated maximal covering location problem (CMCLP) identified as the most suitable for this study.

The results showed that with the requirement of at least 80 beds per facility, considerably fewer facilities would be needed in 2026, in both scenarios, than were operating in 2011. Facility numbers decreased in both scenarios in 15 of 20 DHBs. Of the five DHBs that experienced an increase in facility numbers - Bay of Plenty, Capital and Coast, Counties Manukau, Hutt and Waitemata - Waitemata had the most significant increase at 43 facilities, over twice the 2011 level. Southern on the other hand, required 29 fewer facilities.

Despite the overall lower number of facilities compared with 2011, the chosen locations improved the spatial accessibility of ARCFs overall. As a result of using DHB population to predict the likely number of facilities and beds required to meet demand in 2026, the resulting bed-to-population ratios were effectively identical between DHBs. Mean travel times to nearest facility were lower overall in both scenarios compared to 2011, and were lower in

most DHBs. Several DHBs recorded large reductions in travel time, most notably Tairāwhiti where average travel time to nearest facility fell from 26 minutes to ten in Scenario A, a reduction of over 60%. Whanganui, Waitemata, Lakes, Hutt, Counties Manukau, Capital and Coast, and Auckland all had travel time reductions of over 25%. Large improvements were also seen in some DHBs with the proportion of population under 30 minutes from a facility increasing, most notably West Coast where it increased from 65% to 82% and Whanganui where it increased from 85% to 96%. Proportion over an hour also fell from 10% to zero in Tairāwhiti in both scenarios.

However not all DHB registered improvements. Bay of Plenty, Southern, Taranaki and Wairarapa all recorded increases in average travel time. A similar regress was seen with the proportion of population under 30 minutes decreasing for each of these DHBs. With the exception of Bay of Plenty each of these DHBs previously had provider to population ratios below the national average, and each were allocated considerably fewer facilities in both scenarios.

Variation in spatial accessibility by urban/rural category remained in both scenarios. However the degree of the variation was reduced. The proportion of population by travel time was very similar in both scenarios to proportions in 2011. However, a greater proportion of the population is located within 15 minutes for all categories except for highly rural remote areas which decreased in both scenarios and areas outside urban/rural profile which remain the same. The largest improvement in both scenarios was seen in rural areas with moderate urban influence. However, the proportion under an hour decreased in both scenarios for highly rural and remote areas, rural areas with moderate urban influence and with high urban influence. This effect could be linked to the small populations in this areas being less significant to this analysis (Rahman & Smith, 2000) or the capacitated maximal covering location problem not having an assigned maximum travel time.

Similarly, there was still considerable variation in bed to population ratios between urban and rural areas, but the extent of variation was reduced. Where in 2011 all rural areas were below 30% of the national rate, they were all above 40% in scenario A and above 35% in scenario B.

GIS methods were shown to have been used in health and non-health applications to identify from potential locations those which would most equitably supply the populations. Methods most appropriate to this context were selected in the methodology. The results of the subsequent analyses clearly show that these methods have the potential to improve the equity of the distribution of locations of ARCFs in New Zealand. The GIS methods used were shown to reduce the travel time to nearest facility overall, despite falling numbers of facilities, and

reduce the level of variation between DHBs and urban and rural areas. The methods did not remove inequality in the distribution of locations but suggested new locations which go some way to reducing the overall inequity.

## 7.2. Appropriateness of methods

This research set out to answer the central research question: *to what extent can geographic information science (GIS) methods be used to assess current and identify and assess potential future locations of aged residential care facilities in New Zealand?* The results chapter assessed current locations for their equity of distribution (spatial access) and identified and assessed potential future locations. However to properly understand *to what extent GIS methods can be used*, serious consideration needs to be paid to the appropriateness of the methods for this application.

The GIS methods used in this thesis were principally chosen for their simplicity and ease of implementation. The spatial access measures selected are easy to interpret by decision makers (Guagliardo, 2004), the suitability analysis methods used allow for the concentration of large amounts of decision making data into manageable information and are easily implemented in a GIS environment (Malczewski, 2000), and the location-allocation analysis allows thousands of potential combinations of new and existing facility locations to be assessed and the best combination identified with a single operation. With improvements in GIS and personal computing power and the proliferation of spatial data the methods presented here are attainable for planners (Cromley & McLafferty, 2002). Further, all of the data used in this analysis was freely available online and all the analysis undertaken on a personal computer with off-the-shelf GIS software.

However, the methods used in this thesis do have some key limitations. Perhaps the most obvious of which is that the chosen locations might not be suitable for the location of ARCFs. The unacceptability could be due to any number of reasons, most obvious of which might be availability of land at the potential or chosen locations. While this analysis is designed to select an area (meshblock) within which to place a facility, rather than a specific parcel of land, there is still a high potential that the area will not contain any available sites on which to construct a facility. This is perhaps particularly likely in urban areas where meshblocks are much smaller and more densely developed due to concentrated populations.

Related to this is the issue that the list of spatial attributes identified by the literature search and upon which decision makers assigned importance is not comprehensive. This lack of comprehensive list of spatial attributes has been identified as a common failing of GIS-based land suitability analyses (Malczewski, 2000), and as discussed in the data chapter, six of the 15

identified spatial attributes had to be excluded because of incomplete or unavailable data. Further, there are likely many more spatial attributes that are important to decision makers that were not identified in the literature review. As a result, the potential future locations identified may result in unacceptable locations for providers (Keeney, 1982). To gather a fuller range of spatial attributes will require empirical research, specific to the New Zealand context.

Likewise, areas may be more or less desirable based on many spatial attributes, many of which may be difficult to apply to a spatial context. Other attributes may have a clear spatial dimension, such as land availability or land cost, but are very dynamic and hard to model. Datasets will need to be highly up-to-date if such dynamic spatial attributes are to be measured.

From the other side of the equation, not all the factors that influence visitation by friends and family are spatial in nature. As discussed in the literature review, access to health services entails more than just spatial factors. While travel time and distance has been identified as the most important factor in dictating many studies, the aspatial dimensions, *acceptability*, *affordability* and *accommodation* could play as much of a role (or more) in determining the likelihood of a person visiting friends or family in aged residential care (Penchansky & Thomas, 1981). The impact of factors such as restrictive visiting hours, uncomfortable visiting environments, and costs of transport have been identified by many other authors (Hook et al., 1982; Russell & Foreman, 2002). Facilitating visitation by friends and family for people in ARCFs will not be entirely successful unless all barriers addressed.

The reliance on future projections also poses problems. The analysis assumes that all factors related to where a facility should go, with the exception of future population projections, are temporally static. It assumes that the road network, the location of important spatial attributes and all administrative boundaries stay the same over the study period. It also assumes that provider preferences will not change and that no new models of care will be developed. This is problematic as each of these attributes (and probably many more) have the potential to change. To minimise the impact of potential change data must be as up-to-date as possible at the time of analysis.

There are also some methodological limitations that warrant consideration. Firstly, travel time as measured in this analysis is calculated from a population point (area unit centroid) to facility location rather than from the residential address of each person. As explained in the data chapter, the use of area unit centroids instead of meshblock centroids or residential addresses was the result of area units being the finest resolution of population projections available from Statistics New Zealand. This may have a particular effect in rural areas where area units are



much larger due to lower populations, and the difference in travel time between centroid and actual address may be pronounced, especially in large area units. Previous studies of access to health care facilities in New Zealand have demonstrated that using administrative centroids over residential addresses can cause substantial underestimation of travel time (Brabyn & Barnett, 2004).

Lastly, the analysis does not account for alternative transportation networks and alternative transport modes. This thesis performed the location-allocation analysis and measured travel time to nearest facility using just a single road network, with private automobile as the single mode of transportation. International studies have shown that many visitors, often older friends, access ARCFs by public transportation (Bernoth & Dietsch, 2012). Future applications of these methods would benefit from the inclusion of a public transport dimension.

### 7.3. Policy context

A further restriction on the *extent to which* GIS methods can be affectively applied is the policy context of the aged residential care sector in New Zealand. The results of this study and of potential future applications exist within an established policy context which requires some consideration.

A first consideration is the extent to which DHBs can dictate the chosen location of an ARCF. As identified in the introduction, this method assumes that DHBs have full control as contractors of care over the where the care must be provided. There is however no guarantee that is the case. While the DHB may decide to require that a facility location is within a fixed area, it still requires a provider to agree to the conditions of the contract.

The second consideration is the competing commercial priorities of providers as private businesses, both for-profit and not-for-profit. It might be expected that were DHBs to place strict conditions on the locations of ARCFs, providers may not be able to recoup the same return on their investment that building a facility in their preferred location might return. As identified in the literature review, the majority of facilities built in recent years have been for-profit (Grant Thornton, 2010). Further, the majority of facilities charge some form of copayment to residents for the provision of services that exceed the requirements of the ARRC (Grant Thornton, 2010). It is conceivable that for-profit providers target placement of facilities where they might expect a significant proportion of the population to be willing and financially able to pay a copayment for high service levels. With the DHB assign strict conditions on the location of the service provision, they might struggle to attract for-profit providers.

A closely related matter is the spatial relationships of ARCFs with retirement villages. As identified in both the literature review and the survey of providers, proximity to retirement villages is important for providers when deciding the location of a facility. These retirement villages act - in the words of one decision maker - as 'feeders for service', whereby people living in the village will transition into the co-located ARCF when their care needs get higher, providing 'continuity of care' for residents (Grant Thornton, 2010). Subsequently, 37% of facilities in New Zealand are now colocated with retirement villages (Grant Thornton, 2010). However, this proximal binding of ARCFs to retirement villages has been criticised for creating a two-tier system whereby high income older people have access to this continuum of care and low income older people do not (Alex Chalmers, 2005; Todd, 2011). Low income alternatives to retirement villages have been identified as a possible solution to this issue (Grant Thornton, 2010). The placement of retirement villages is not directly influenced by DHBs. Where DHBs contract for providers to supply aged residential care, retirement villages are generally commercial operations placed entirely at the behest of the provider and located where providers feel they can maximise their profits. Strict conditions on the location of service providers may affect providers' ability to colocate ARCFs with retirement villages and minimise the 'continuity of care' for residents able to pay for retirement villages (Alex Chalmers, 2005).

Finally, there are financial limitations on the capacities of DHBs to implement these methods for potential facility selection. As already discussed, for-profit providers are likely choose locations based on their ability to make a profit, and placing conditions on the location of facilities may affect their ability to do so. For DHBs to encourage providers to construct facilities in more optimal locations, financial incentives might be one manner to persuade them. However DHBs may not be able afford to spend more on care, particularly as the income earning proportion of the population decreases with an aging population (Creedy & Enright, 2010).

Despite these limitations, the application of the GIS methods presented here still has considerable potential for improving the spatial access to ARCFs. GIS provides planners with the ability to identify areas of poor access, and could be used to plan where future facilities should go to maximise equity within an imperfect system. While the use of 'full-system planning', by which every new facility is located through use of suitability and location-allocation analyses might be optimistic, these methods could be used to locate a subset of new facilities in areas where they are needed most.

## 8. Conclusions

### 8.1. Overview

Over the previous chapters this thesis has investigated to what extent geographic information science (GIS) methods could be used to assess current and identify and assess potential future locations of ARCFs in New Zealand. To answer this, three research objectives were outlined: [1] to describe and measure the current accessibility of aged residential care facilities, [2] to identify areas that are likely to be suitable to providers for the placement of aged residential care facilities in New Zealand and [3] to determine (from the potential locations) where the new facilities should go so that spatial accessibility is maximised.

A combination of GIS methods were used to address these three objectives. To describe and measure the current spatial accessibility of ARCFs a combination of travel impedance (time) to nearest provider and bed-to-population ratios was used. To identify areas likely to be suitable to providers for the placement of new facilities providers were surveyed on the spatial attributes important to them when deciding where to place a new facility and the results were combined using WLC and maps of potentially suitable locations generated. To determine (from the potential locations) where the new facilities should go so that travel time for family and friends is minimised a maximal covering location-allocation model was used. Location-allocation models were run for each DHB against two demand scenarios: Scenario A (low demand) and Scenario B (high demand). The methods used to measure the current spatial accessibility were then repeated for the chosen locations.

### 8.2. Findings

The results of this research suggested two principal findings. First, the GIS methods used in this thesis demonstrate clearly that there is considerable variation between areas in the spatial access to ARCFs in New Zealand. Primarily, people in rural areas typically have poorer spatial access than those in urban areas. Further, some DHBs were found to have very high travel times on average from population points to the nearest facility. The results support claims that people in rural areas often have to travel much further to access ARCFs than people in urban areas. However, the results do not appear to support the claims that people in poorer areas have poorer spatial access to ARCFs than people in wealthier areas.

Second, the results highlight the potential of GIS methods to improve the equity of the distribution of locations of ARCFs in New Zealand. The GIS methods used were shown to reduce the travel time to nearest facility overall, despite falling numbers of facilities, and reduce the level of variation between DHBs and urban and rural areas. While the methods did

not remove inequality in the distribution of locations the suggested locations would reduce inequality.

### **8.3. Contribution to the literature**

This thesis identified a gap in the literature in New Zealand for a study investigating spatial access to ARCFs nationally, and internationally for a study investigating where to place future ARCFs so that equity is maximised and travel times for family and friends minimised. It is hoped that this thesis has made some progress towards addressing these gaps. This thesis is also somewhat unique in that it seeks address where to place ARCFs where they will be both acceptable to both providers and to clients.

### **8.4. Shortcomings of research**

As per the discussion chapter, there were shortcomings with this research, primarily around assumptions made in the modelling process and constraints on data availability. In summary, the research required several primary assumptions: [1] The study assumes that all factors related to where a facility should go, with the exception of future population projections, are temporally static and will not change over the projection period. [2] It assumes that DHBs have the utility to dictate the chosen location of an ARCF. [3] It assumes that the locations identified are appropriate to aged residential care providers as facility locations.

Second, constraints on data availability dictated several methodological decisions: [1] The lack of accurate facility type data meant that the analysis could not be split by the four ARCF types. [2] The lack of research identifying distance decay functions for the impact of increasing travel time on the likelihood of visitation meant that more complex spatial accessibility measures could not be used. [3] Constraints on time meant that a list of potentially important spatial attributes had to be gathered from the literature rather than by a survey providers. [4] A lack of spatial data meant that not all spatial attributes identified as important to providers when deciding where to place a facility could be modelled. [5] The lack of national public transportation shapefile or network dataset meant that access via public transportation could not be modelled.

### **8.5. Recommendations for future research**

Despite these limitations, the use of the GIS methods presented here have considerable potential for use in improving the spatial accessibility of ARCFs in New Zealand. To be of the most use to decision makers some future research is recommended: [1] Future research should empirically investigate the impact of travel time on the frequency and duration of visitation by family and friends in New Zealand to develop targets around maximum

acceptable travel times and to develop distance decay functions for modelling spatial access. [2] Future research should also explore in more detail which spatial attributes are important to decision makers, and to what extent, when deciding where to place a future aged residential care facilities. As more spatial data becomes available, research should model these spatial attributes to more optimally identify locations suitable to providers. [3] Finally, future applications of this method should consider including access via public transport network when performing the location-allocation analyses.



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## **Appendices**

### **Appendix one: Minnesota and Montana spatial attributes**

Category	Spatial attribute	Description	Montana	Minnesota	Suitable to NZ Context	National dataset Available
Emergency response	Fire department response time to site	Fire department response to site within x time	Yes	No	Yes	Yes
	Hydrant within x-distance of site	Hydrant within x distance of site	Yes	No	Yes	No
	Critical access (emergency) hospital	Region has a critical access hospital	Yes	No	Yes	Yes
	Ambulance response time to site	Ambulance response to site within x-time	Yes	No	Yes	Yes
	Acute care hospital	Community has an acute care hospital/critical access hospital of sufficient size	Yes	Yes	Yes	Yes
Associated health services	Distance to related health facilities	Site within x time of existing community-based outpatient clinic (CBOC) or a veterans administration medical center (VAMC).	No	Yes	No	No
	Availability of dentists	Dentists available in region	Yes	Yes	Yes	Yes
	Travel time to dentists	Dentists within x time of site	Yes	Yes	Yes	Yes
	Availability of GPs	GPs available in region	Yes	Yes	Yes	Yes
	Travel time to registered nurses (RNs)	RNs within x time of site	No	Yes	Yes	No
	Availability of licensed practice nurses (LPNs)	LPNs available in region	No	Yes	No	No
	Availability of psychologists in region	Psychologist available in region	Yes	Yes	Yes	Yes
	Number of psychiatrists in region	Psychiatrists available in region	No	Yes	Yes	Yes
	Social workers	Social workers available in region	Yes	No	Yes	No
	Physical therapist	Physical therapists available in region	Yes	No	Yes	No

Utilities	Single phase power	Single Phase Power available in region	Yes	No	Yes	Yes
	Available 1500 GPM water system	1500 GPM water system available in region	Yes	No	Yes	No
	Adequate sanitary sewer system	Adequate sanitary sewer system available in region	Yes	No	Yes	No
	Internet/access to T-1 Lines	Internet/access to T-1 Lines available in region	Yes	No	Yes	Yes
	Natural gas availability	Natural Gas available in region	Yes	No	Yes	Yes
	Site access roads	Site has appropriate access roads	Yes	No	Yes	Yes
	Public transportation	Local public services (buses, rail etc.) available in region	Yes	Yes	Yes	No
	Taxi service available	Local taxi service available in region	Yes	Yes	Yes	Yes
Public Transport	Shuttle service available	Local shuttle service available in region	Yes	Yes	Yes	Yes
	Appropriate zoning	Area has appropriate zoning	Yes	No	Yes	Yes
Other	Mortuary services	Mortuary services available in region	Yes	No	Yes	No
	Contractors	Contractors available in region: HVAC, general construction, electrical, etc.	Yes	No	Yes	No

Spatial attributes collected from (Engan Associates & Ulteig, 2009; SW Montana Veterans' Home Site Selection Committee, 2009)

**Appendix two: Site selection survey**

## Study Overview

### Study Overview

Researcher: Jacob Daube, School of Geography, Environment and Earth Sciences, Victoria University of Wellington

I am a Geography student at the School of Geography, Environment and Earth Sciences, Victoria University of Wellington. I am currently undertaking a Masters research thesis under the supervision of Dr Mairead de Roiste and Dr Judith Davey.

My research project examines the spatial accessibility of aged residential care facilities (rest homes, aged care hospitals, secure dementia units or psycho-geriatric units) in New Zealand and explores where future facilities can be placed to meet expected demand increases, whilst maintaining or improving spatial accessibility.

The aim of this questionnaire is to determine the importance of a series of spatial factors when deciding where to place aged residential care facilities. Each of the spatial factors has previously been used internationally for this purpose. The results of this questionnaire will be used to develop the significance of each spatial factor, which will then be combined in a geographic information system (GIS) to identify areas that would potentially be suitable for the placement of aged residential care facilities.

You will be asked to score on sliding scales how important certain spatial factors are. It is envisaged that the questionnaire will take about **15 minutes** to complete. Should you feel the need to withdraw from the project, you may do so at any time before the data are analysed.

Responses collected will form the basis of a research project and will be included in a written report on an anonymous basis. It will not be possible for you to be identified personally. All material will be kept confidential. No other person besides myself (Jacob Daube) and my supervisors, Dr Mairead de Roiste and Dr Judith Davey, will see the responses. The thesis will be submitted for marking and deposited in the Victoria University Library. It is intended that one or more articles will be submitted for publication in scholarly journals. Responses will be destroyed two years after the end of the project.

If you wish to participate, please click on the link below. By following this link you are acknowledging that you have been given and have understood an explanation of this research project, and that you consent to participate in this research.

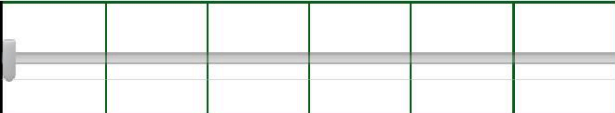
Thank you for your interest and assistance with this research

## Emergency Services

### 24-Hour Emergency Department (ED)

How important is travel time to the nearest 24-hour emergency department when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

	Relatively unimportant			Very important			
	1	2	3	4	5	6	7
Travel time to nearest 24-hour emergency department							

What would be the maximum travel time from a 24-hour emergency department that you would feel comfortable with when

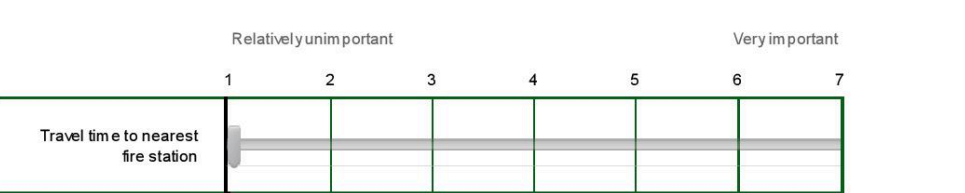
deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

Fire Station

How important is **response time** from the nearest fire station when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.



What would be the maximum response time from a fire station that you would feel comfortable with when deciding where to place an aged residential care facility?

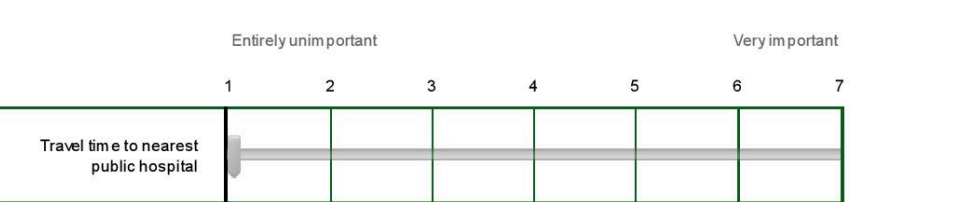
Please write your answer in minutes in the box below

Associated Health Services

Public Hospital

How important is travel time to the nearest public hospital when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.



What would be the maximum travel time from a public hospital that you would feel comfortable with when deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

### General Practitioner (GP)

How important is travel time to the nearest general practitioner when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

	1	2	3	4	5	6	7
Travel time to nearest general practitioner							

What would be the maximum travel time from a general practitioner that you would feel comfortable with when deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

### Dentist

How important is travel time to the nearest dentist when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

	1	2	3	4	5	6	7
Travel time to nearest dentist							

What would be the maximum travel time from a dentist that you would feel comfortable with when deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

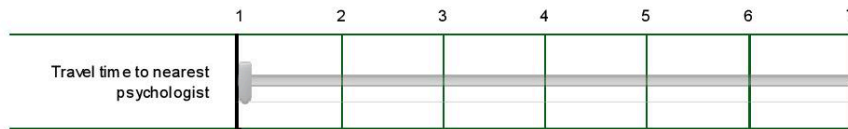
### Psychologist

How important is travel time to the nearest psychologist when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

Relatively unimportant

Very important



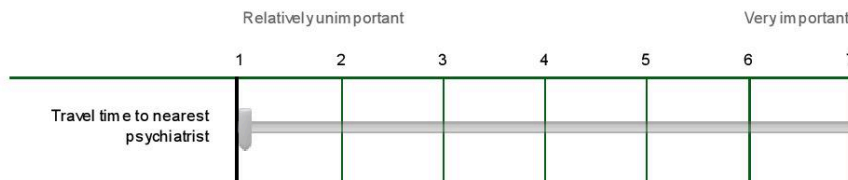
What would be the maximum travel time from a psychologist that you would feel comfortable with when deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

### Psychiatrist

How important is travel time to the nearest psychiatrist when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.



What would be the maximum travel time from a psychiatrist that you would feel comfortable with when deciding where to place an aged residential care facility?

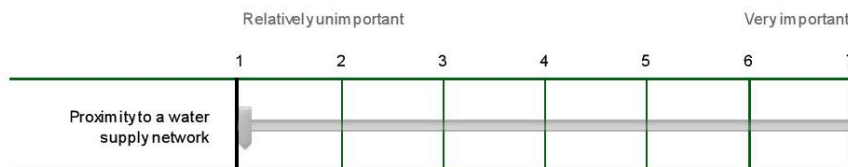
Please write your answer in minutes in the box below

### Utilities

#### Water Supply Network

How important is proximity to a water supply network (water main) when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

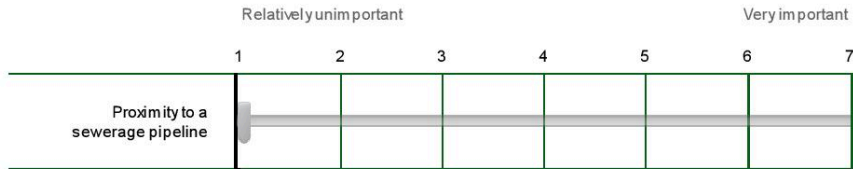




### Sewerage Pipeline

How important is proximity to a sewerage pipeline when deciding where to place an aged residential care facility?

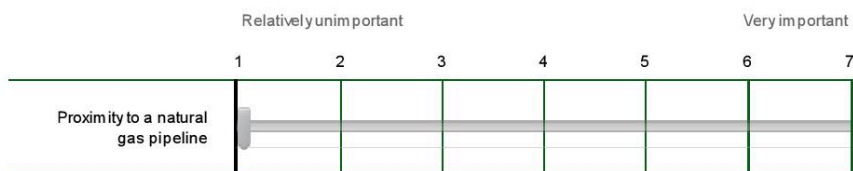
On the line below, please click the position that you feel best reflects its importance.



### Natural Gas Pipeline

How important is proximity to a natural gas pipeline when deciding where to place an aged residential care facility?

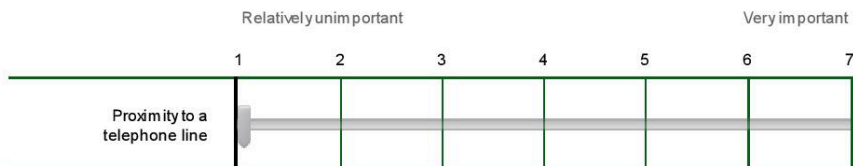
On the line below, please click the position that you feel best reflects its importance.



### Telephone Line

How important is proximity to a telephone line when deciding where to place an aged residential care facility?

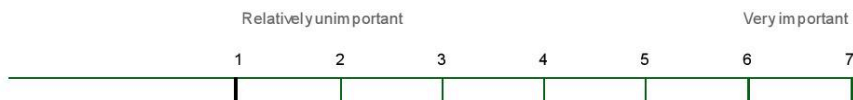
On the line below, please click the position that you feel best reflects its importance.

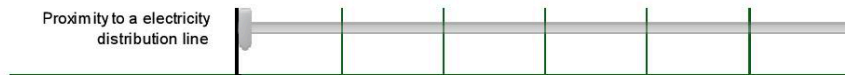


### Electricity Distribution Line

How important is proximity to an electricity distribution line (power line) when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

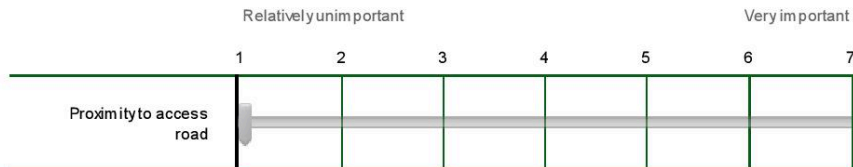




### Access Road

How important is proximity to an access road when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

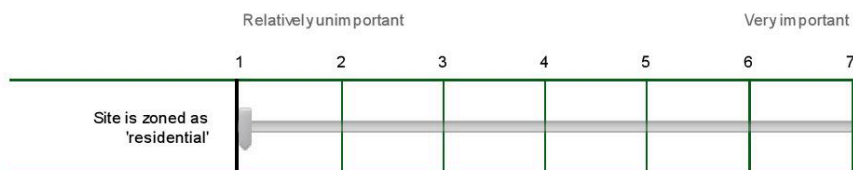


### Zoning

#### Zoning

How important is it that a potential site is zoned as 'residential' when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.

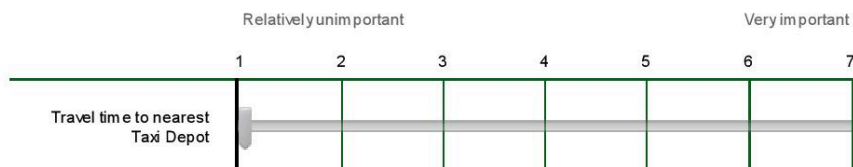


### Public Transport

#### Taxi or Shuttle Depot

How important is travel time to the nearest taxi or shuttle depot when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.



What would be the maximum travel time from a taxi or shuttle depot that you would feel comfortable with when deciding where to place an aged residential care facility?

Please write your answer in minutes in the box below

### Other Spatial Variables

#### Other Spatial Variables

Are there any other spatial variables that you can think of, that you feel are important and that have not been covered so far?

☐ Yes

☐ No

#### Spatial Variable 1

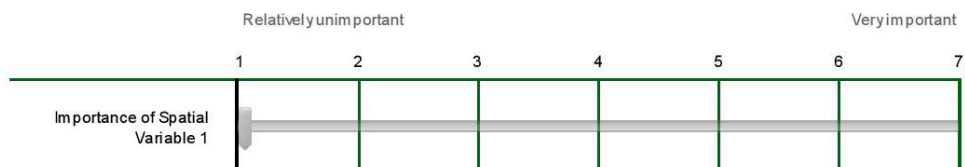
Please write your spatial variable in the box below (i.e. 'travel time to public hospital', or 'proximity to water supply network').

If you have more than one variable to add, place one in the box below and you will be prompted to add more after the next question.

#### Spatial Variable 1: \${q://QID41/ChoiceTextEntryValue}

How important is \${q://QID41/ChoiceTextEntryValue} when deciding where to place an aged residential care facility?

On the line below, please click the position that you feel best reflects its importance.



#### Any Other Spatial Variables

Are there any other spatial variables that you can think of, that you feel are important and that have not been covered so far?

☐ Yes

☐ No

Other spatial attribute questions repeated as required up to ten times.

## Demographics

---

### Provider Type

Which term best describes the provider for whom you work or, if you work for multiple providers, the type of provider for whom you work the most?

- 
- ☐ For Profit
- ☐ Not For Profit

### Aged Residential Care Facilities

How many aged residential care facilities does your company currently operate?

- 
- ☐ 1
- ☐ 2-5
- ☐ 6-9
- ☐ 10 or more

## Other Comments

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### Other Comments

If you have any other comments or insights on the questionnaire or the use of spatial variables in planning where to place aged residential care facilities, please feel free to share them below.

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## **Appendix three: Comparison maps**

Figure 45: Population centroids

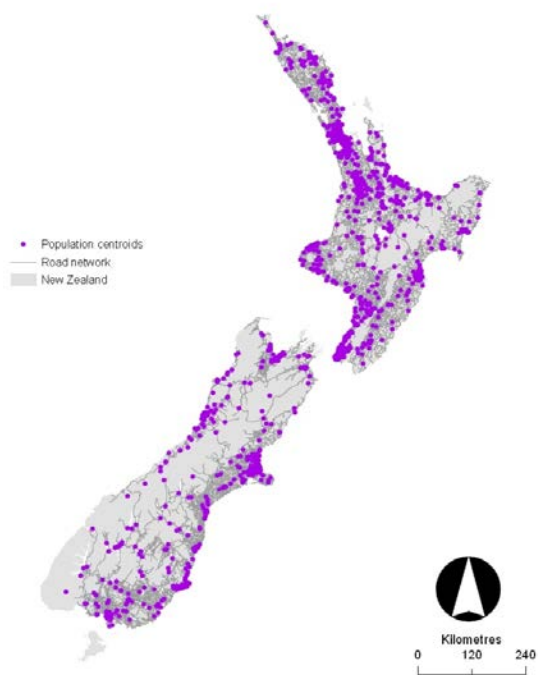


Figure 47: Population by area unit, 2011

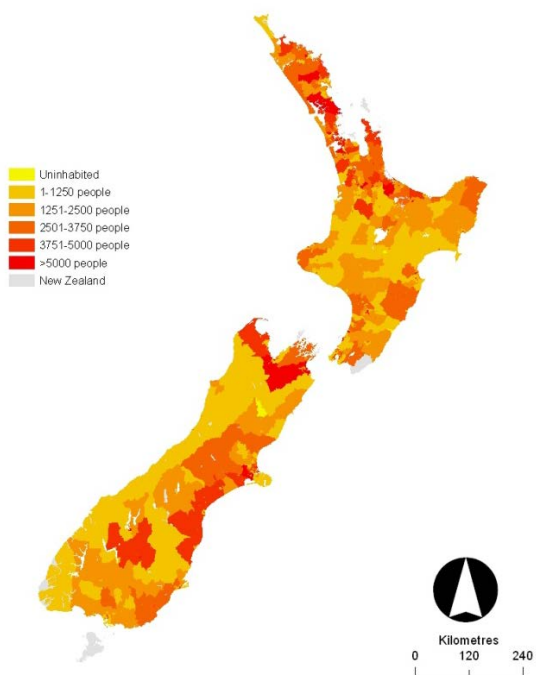


Figure 46: Aged residential care facilities (ARCFs)

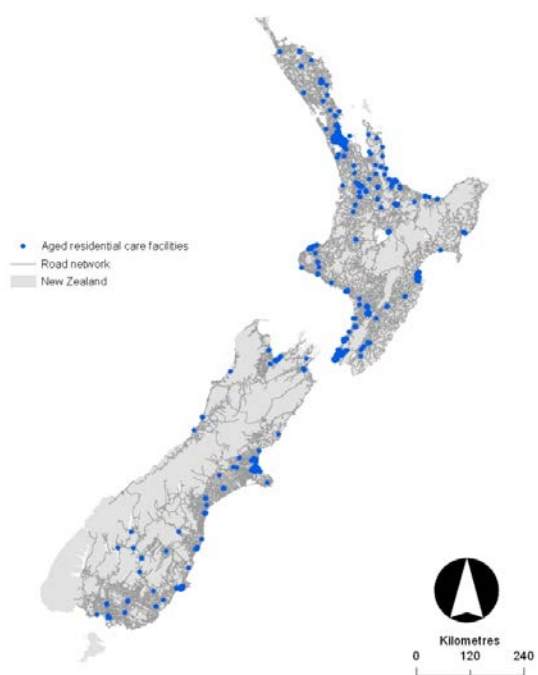


Figure 48: Urban/rural category by area unit

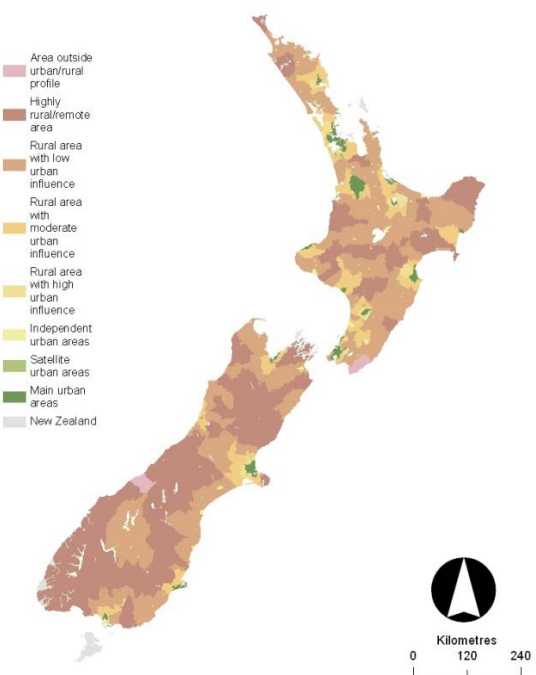


Figure 49: District Health Boards (DHBs)

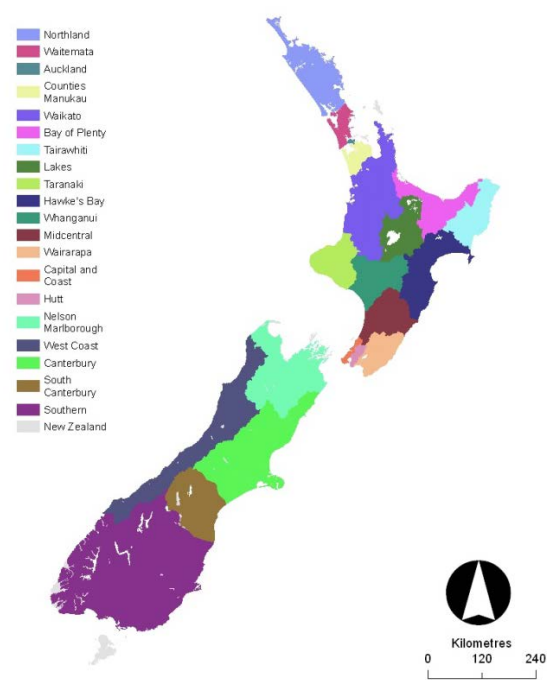
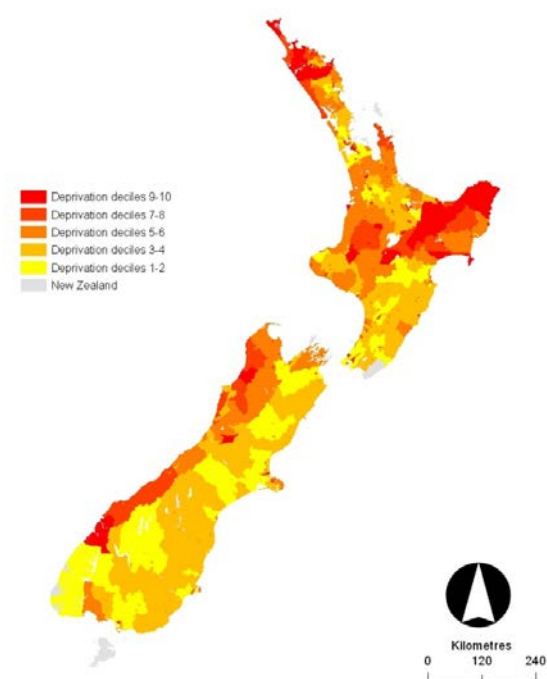


Figure 50: Deprivation decile (NZDep06) by area unit



**Appendix four: Travel time to closest facility by DHB, 2011**



Figure 51: Northland DHB. Travel time to closest facility by area unit

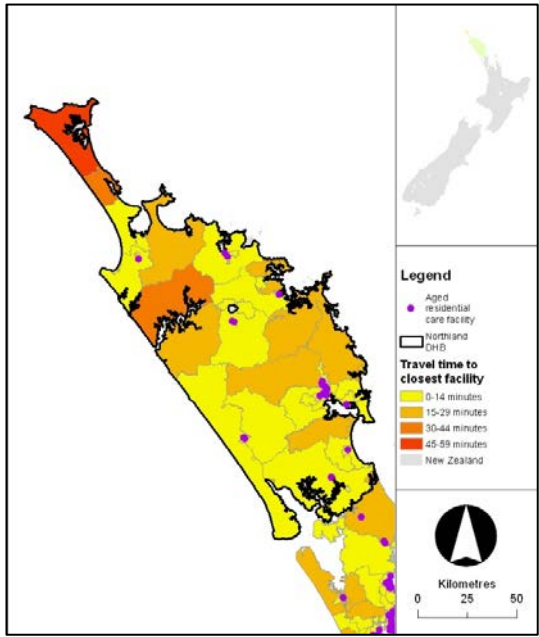


Figure 53: Auckland DHB. Travel time to closest facility by area unit

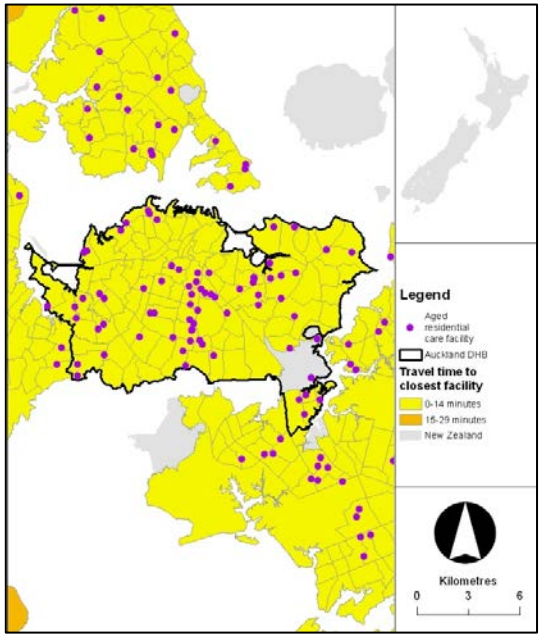


Figure 52: Waitemata DHB. Travel time to closest facility by area unit

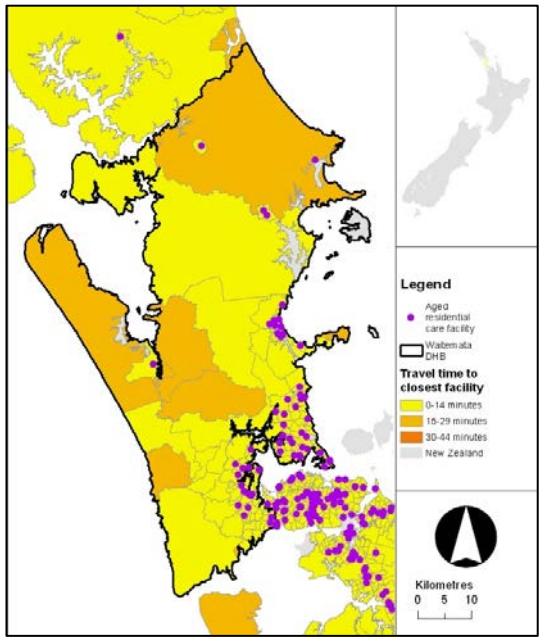


Figure 54: Waikato DHB. Travel time to closest facility by area unit

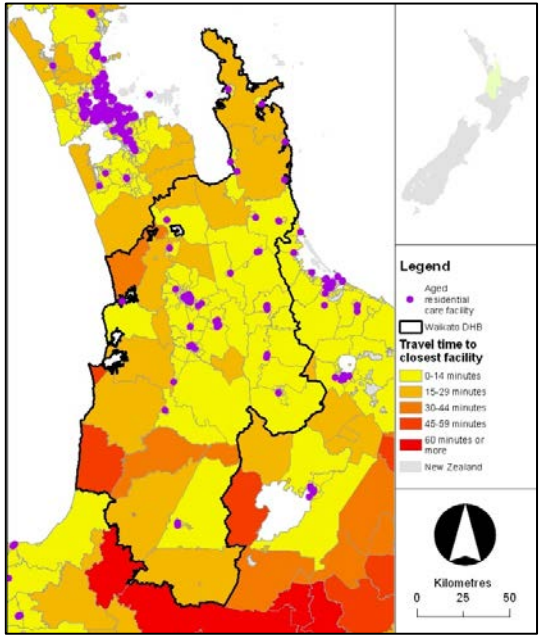


Figure 55: Bay of Plenty DHB. Travel time to closest facility by area unit

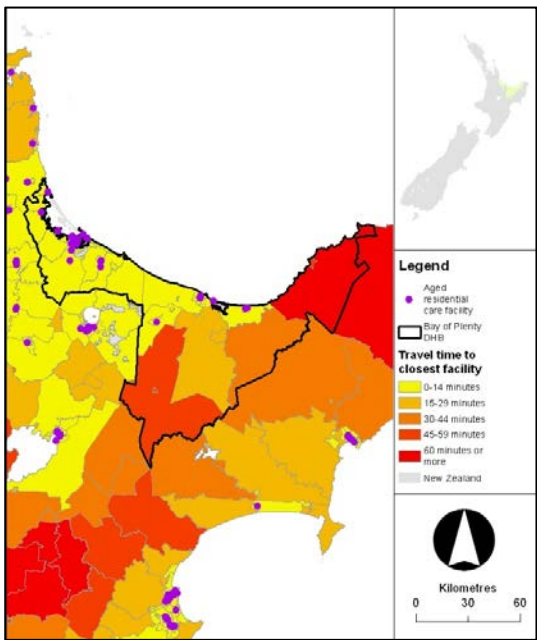


Figure 57: Tairāwhiti DHB. Travel time to closest facility by area unit

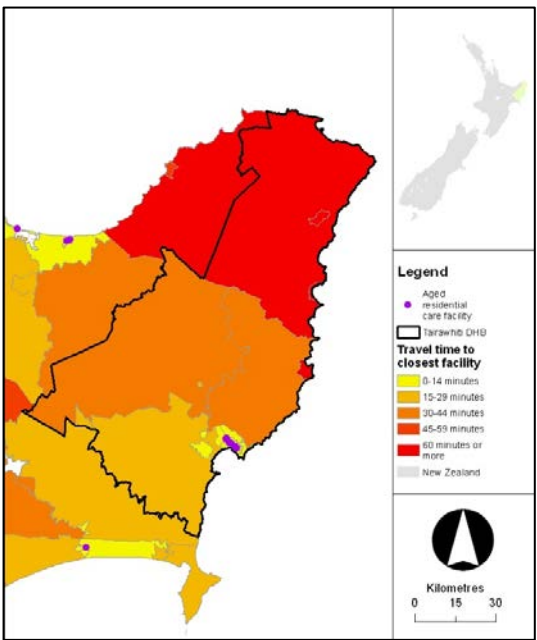


Figure 56: Lakes DHB. Travel time to closest facility by area unit

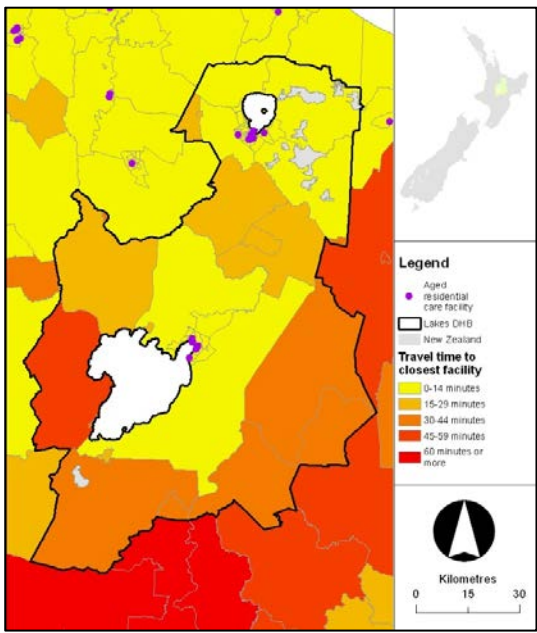


Figure 58: Hawke's Bay. Travel time to closest facility by area unit

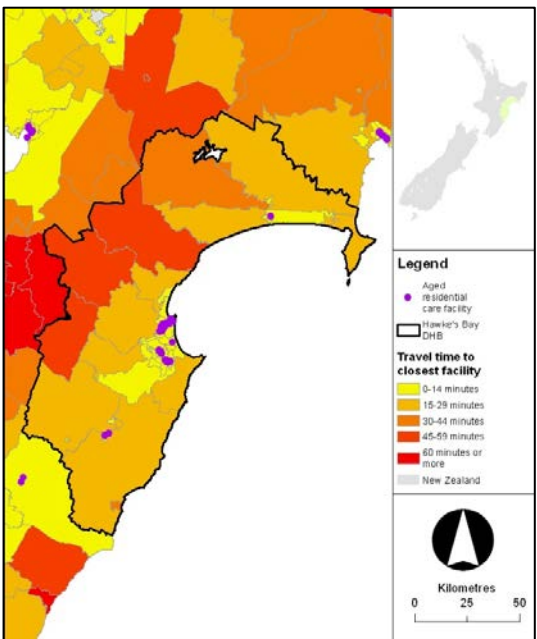


Figure 59: Taranaki DHB. Travel time to closest facility by area unit

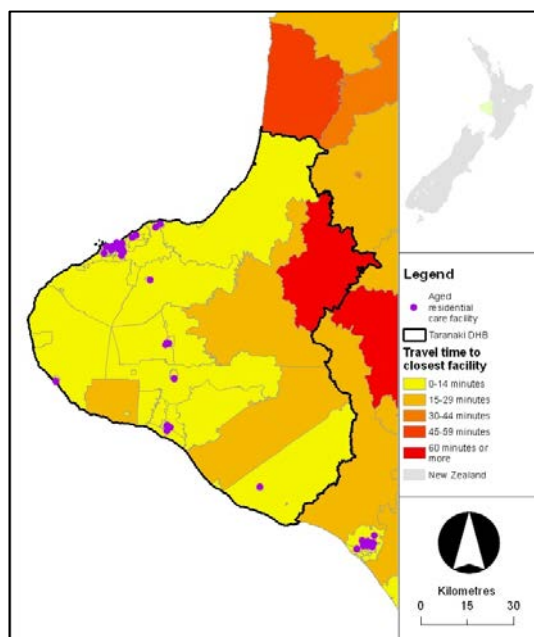


Figure 61: Midcentral DHB. Travel time to closest facility by area unit

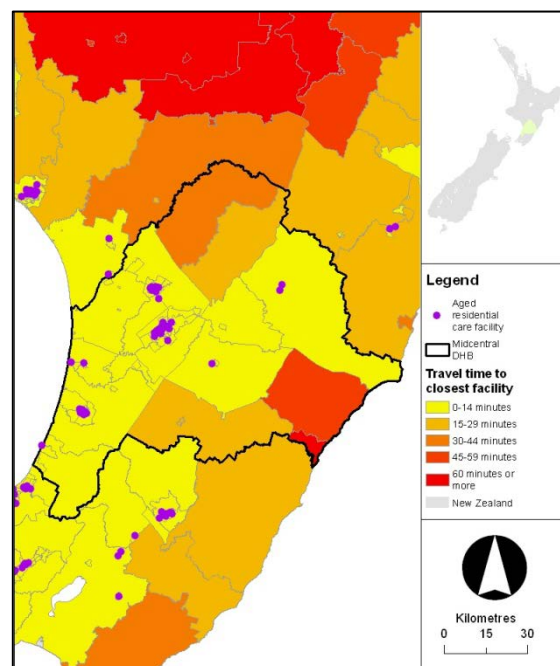


Figure 60: Whanganui DHB. Travel time to closest facility by area unit

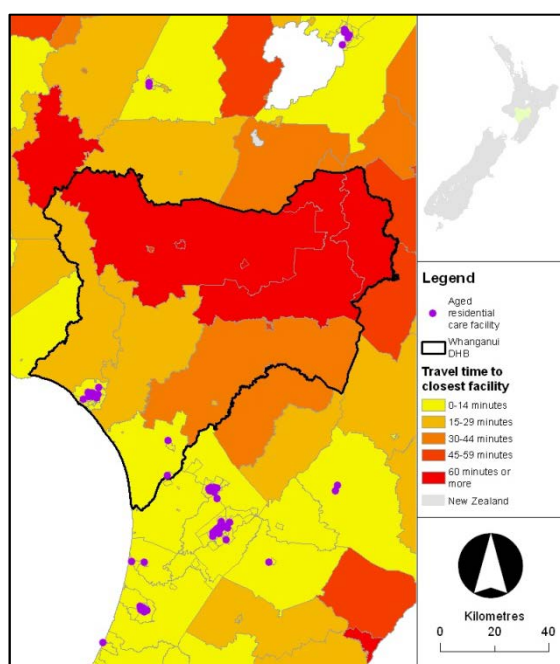


Figure 62: Wairarapa DHB. Travel time to closest facility by area unit

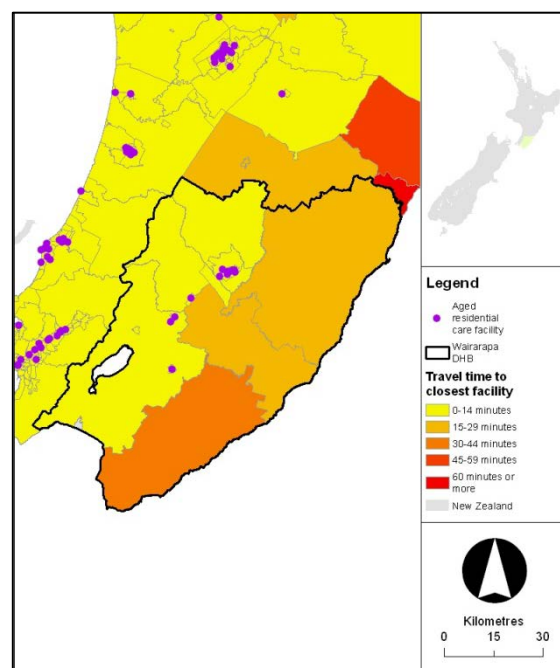




Figure 63: Capital and Coast DHB. Travel time to closest facility by area unit

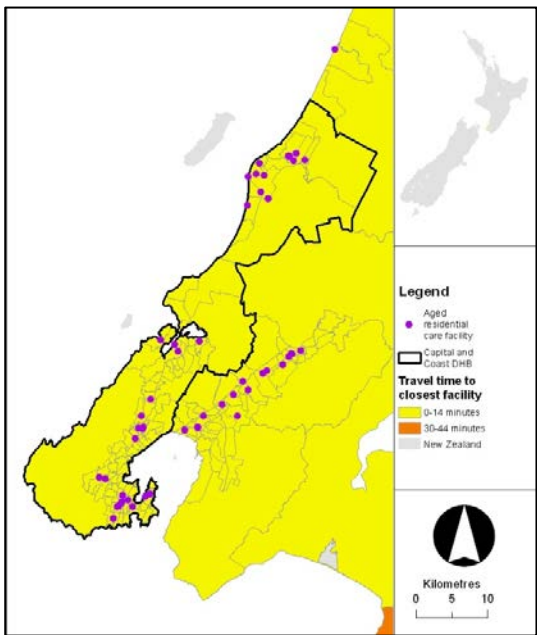


Figure 65: Nelson Marlborough DHB. Travel time to closest facility by area unit

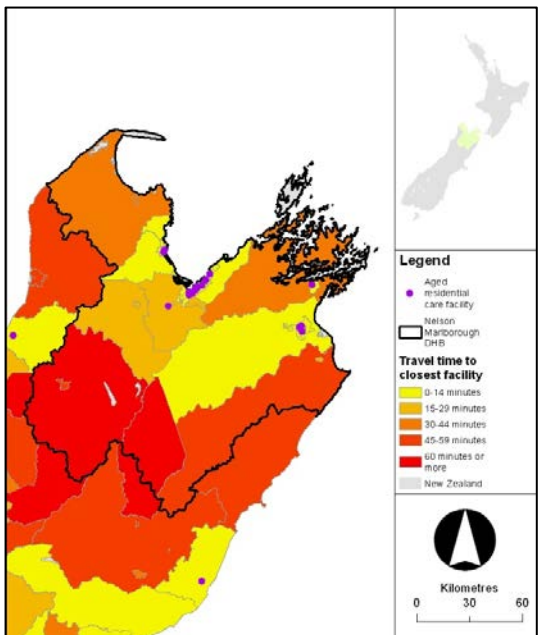


Figure 64: Hutt DHB. Travel time to closest facility by area unit

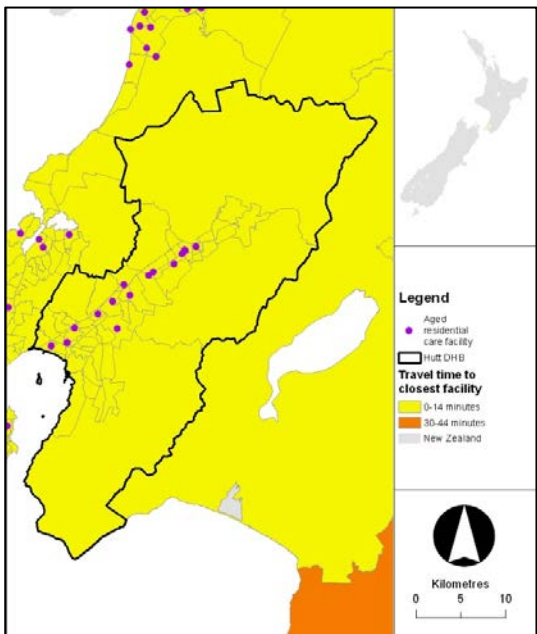


Figure 66: West Coast DHB. Travel time to closest facility by area unit

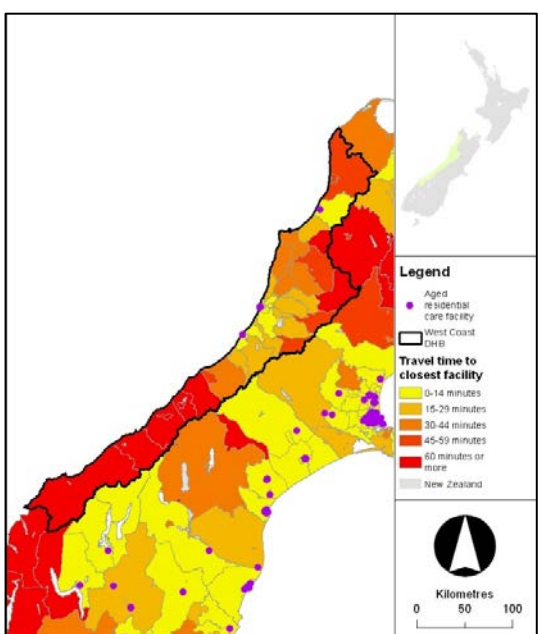


Figure 67: Canterbury DHB. Travel time to closest facility by area unit

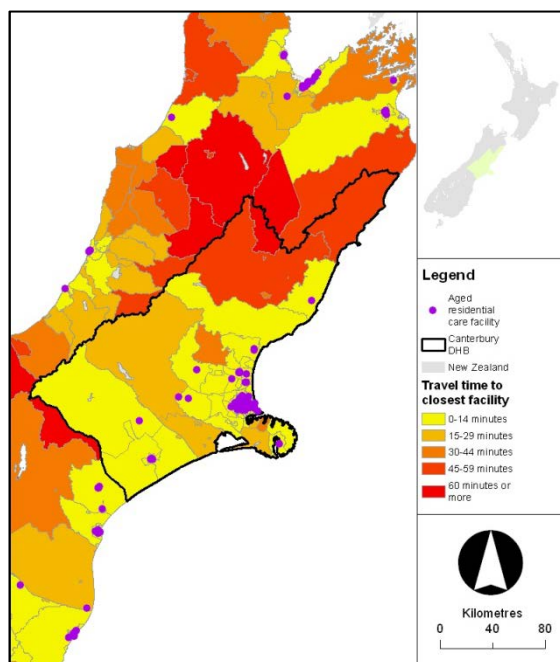


Figure 69: Southern DHB. Travel time to closest facility by area unit

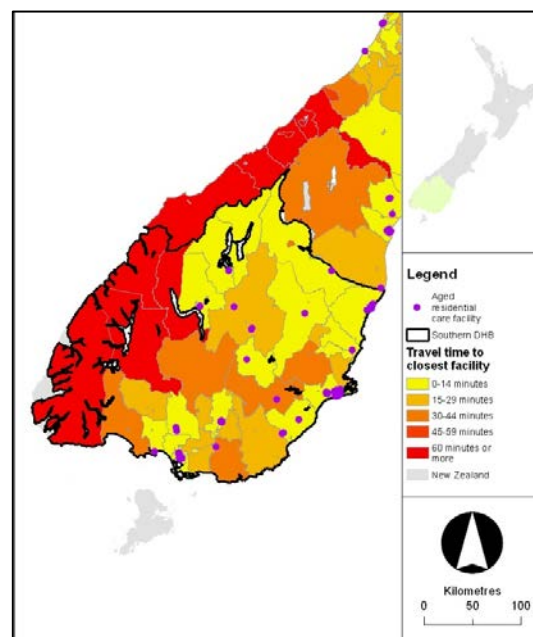
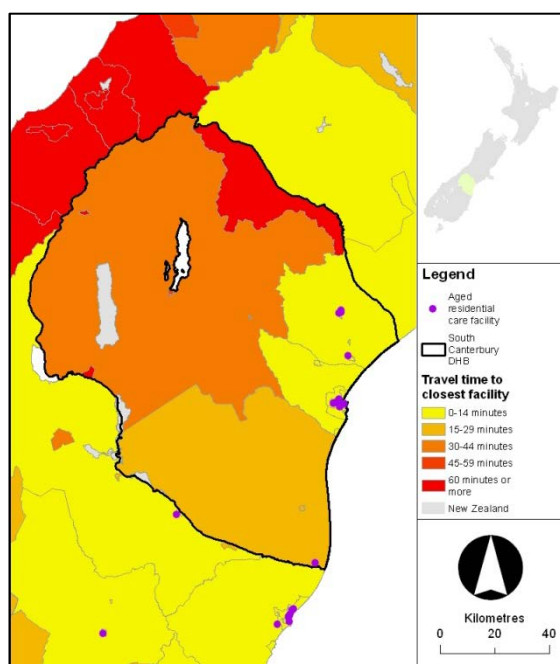


Figure 68: South Canterbury DHB. Travel time to closest facility by area unit



**Appendix five: Potential and chosen facility locations by DHB and scenario, 2026**

Figure 70: Northland DHB. Site selection results, Scenario A

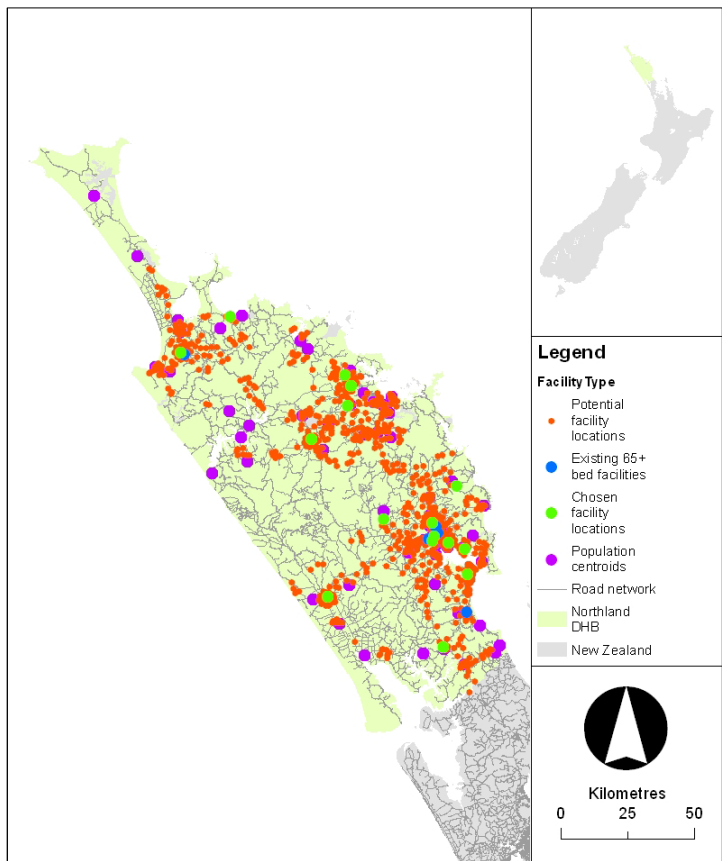


Figure 71: Northland DHB. Site selection results, Scenario B

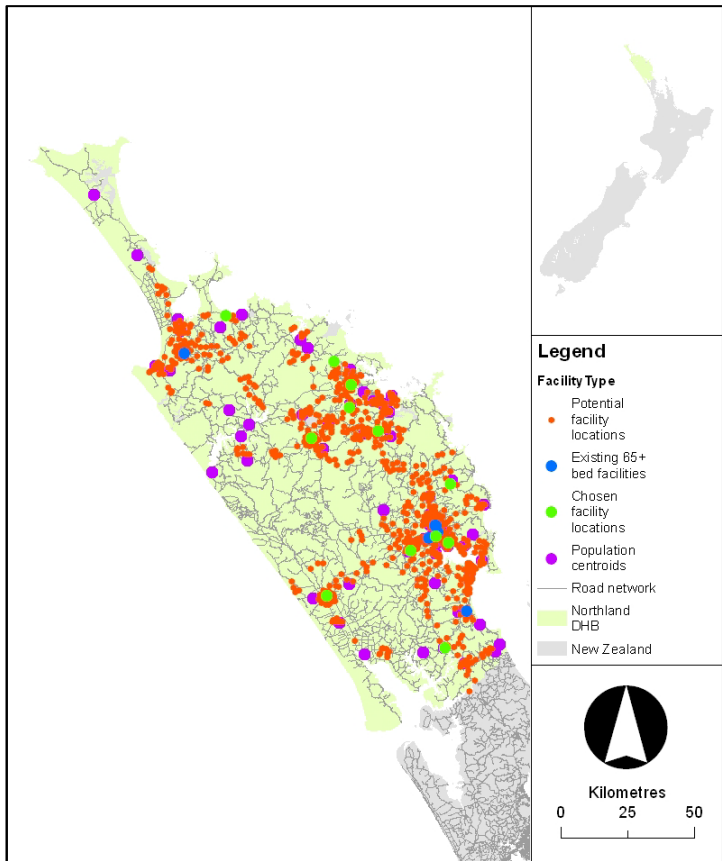


Figure 72: Waitemata DHB. Site selection results, Scenario A

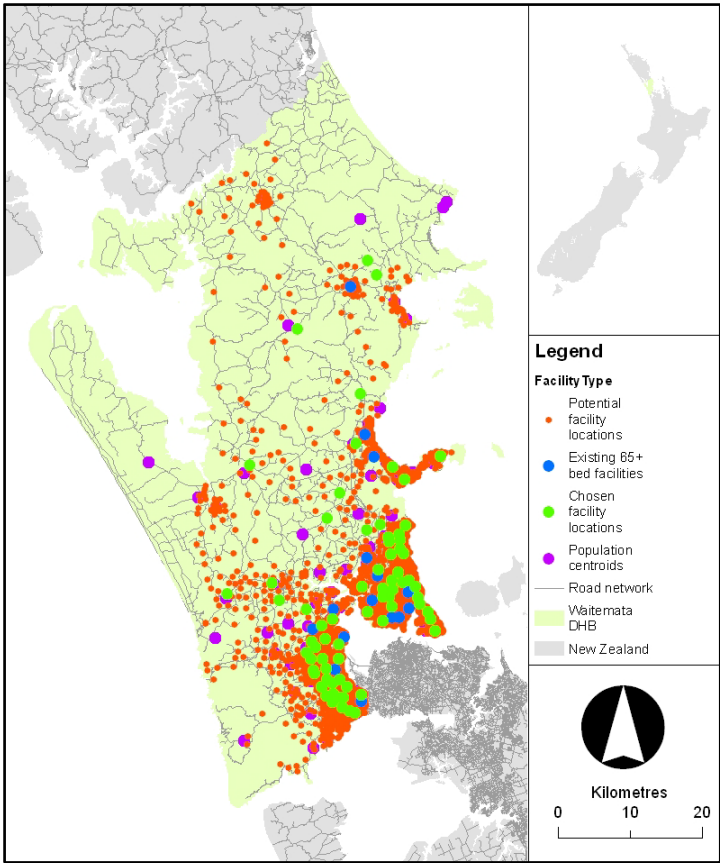


Figure 73: Waitemata DHB. Site selection results, Scenario B

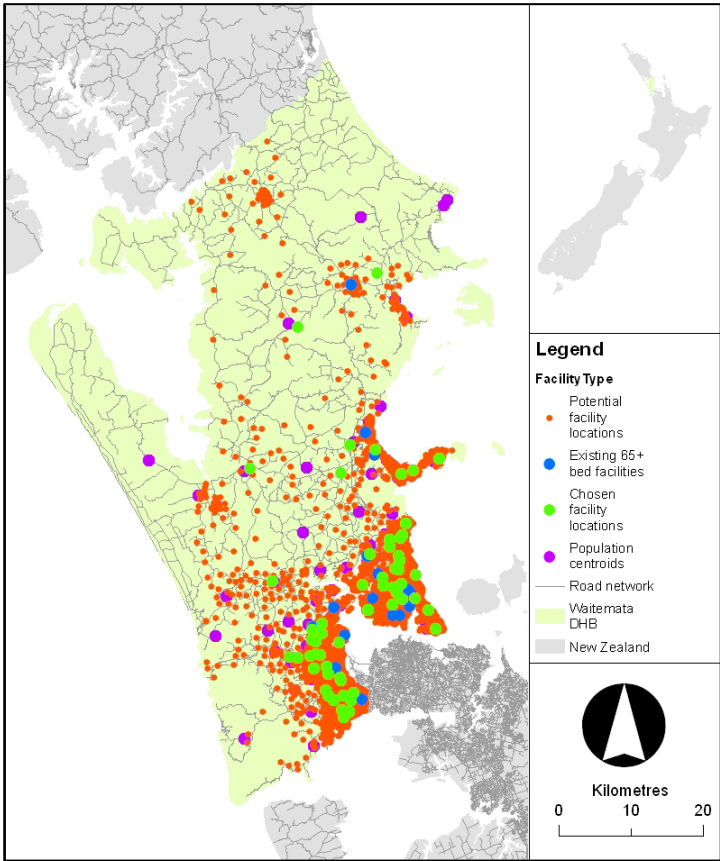




Figure 74: Auckland DHB. Site selection results, Scenario A

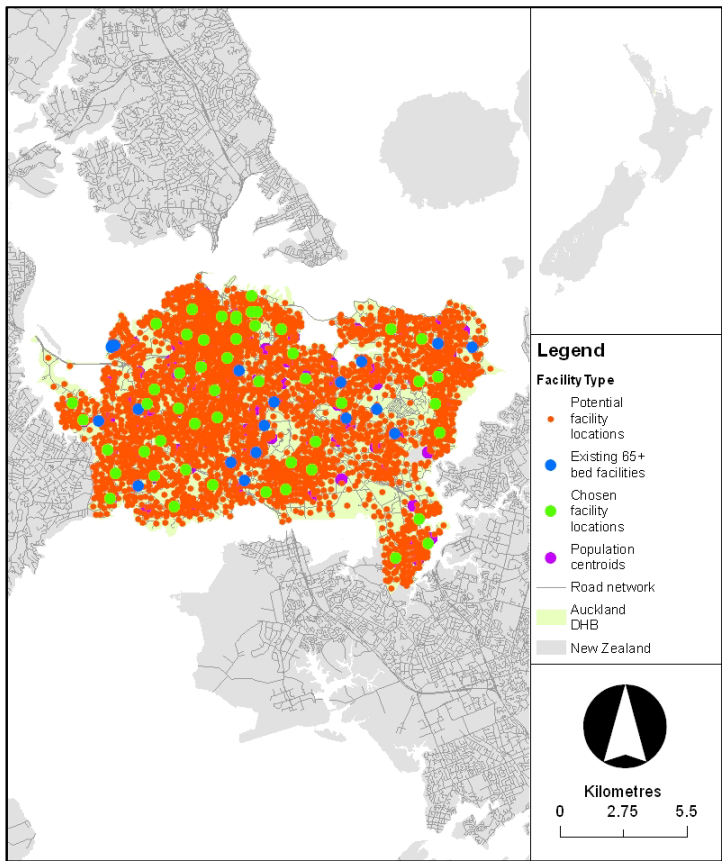


Figure 75: Auckland DHB. Site selection results, Scenario B

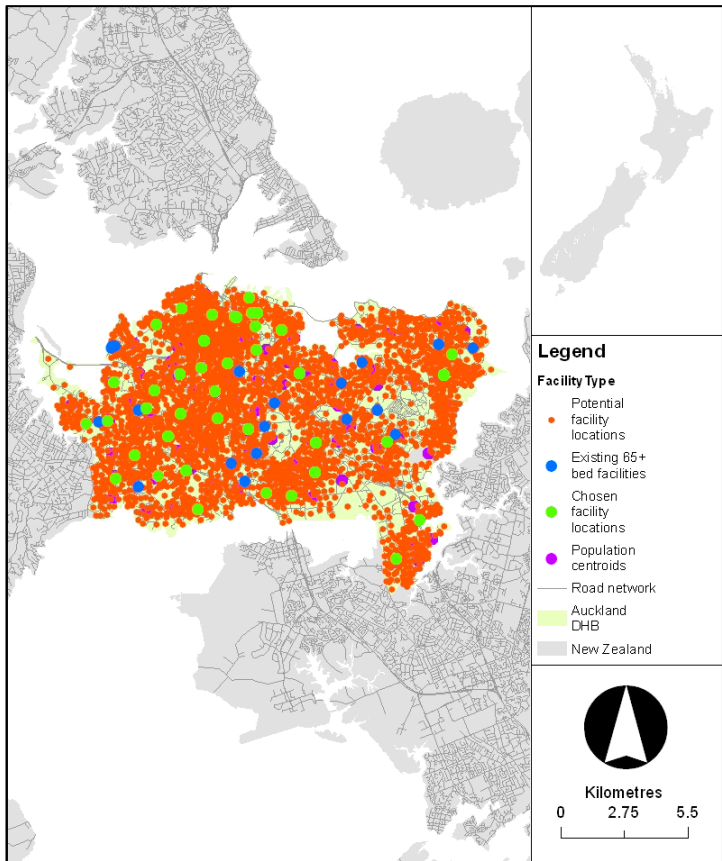


Figure 76: Counties Manukau DHB. Site selection results, Scenario A

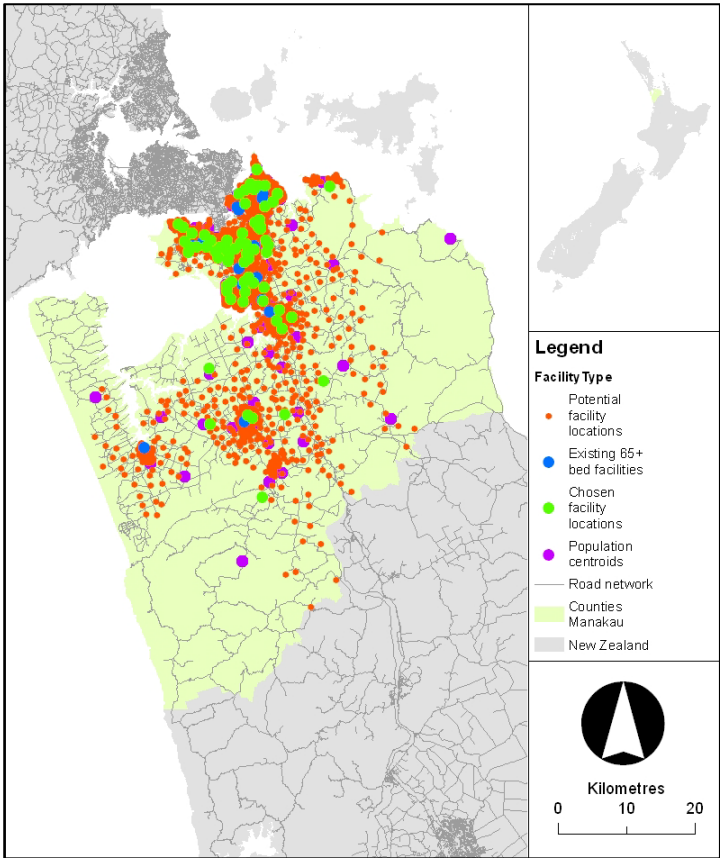


Figure 77: Counties Manukau DHB. Site selection results, Scenario B

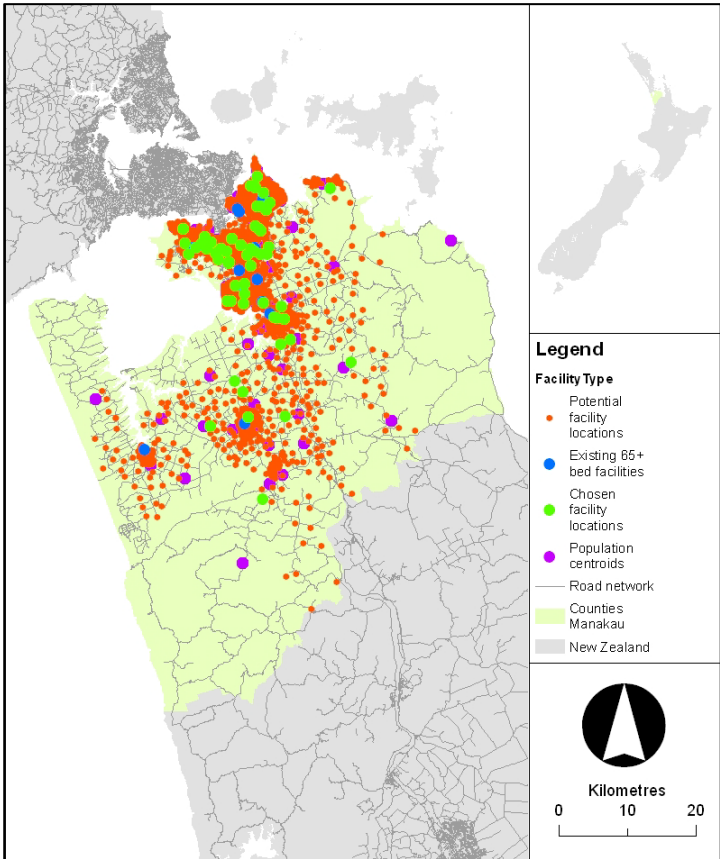


Figure 78: Waikato DHB. Site selection results, Scenario A

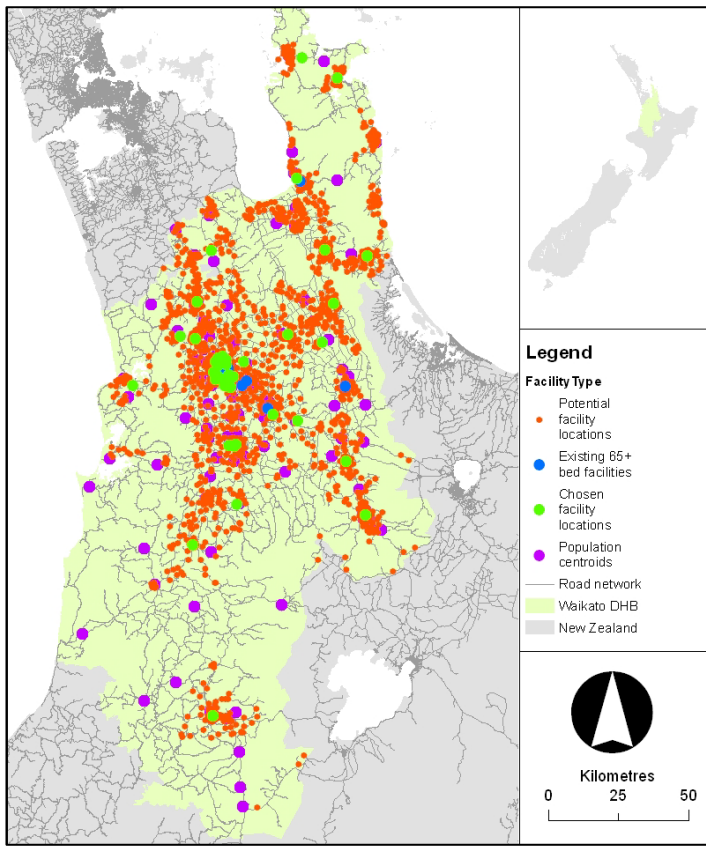


Figure 79: Waikato DHB. Site selection results, Scenario B

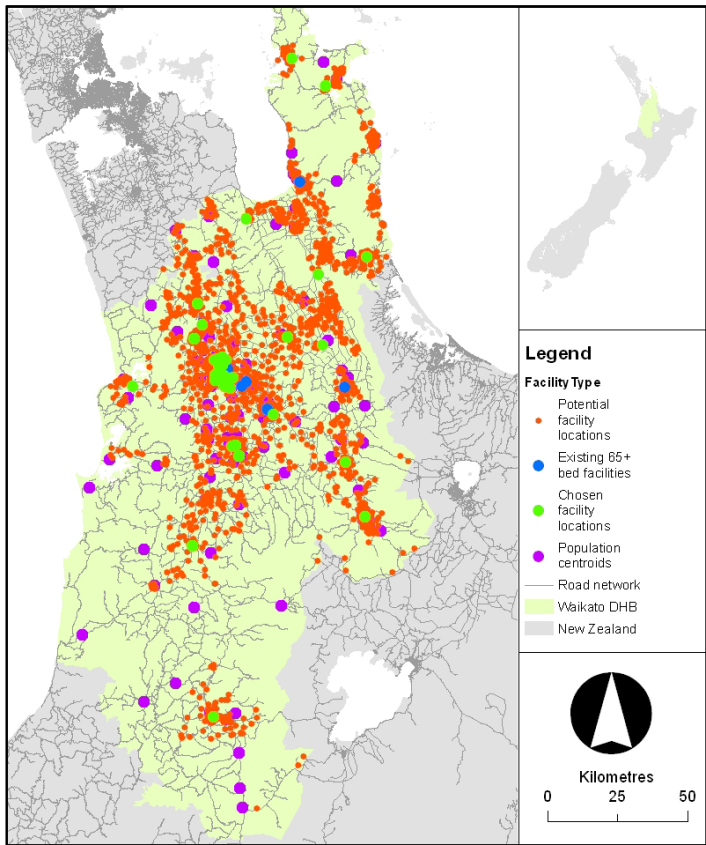


Figure 80: Bay of Plenty DHB. Site selection results, Scenario A

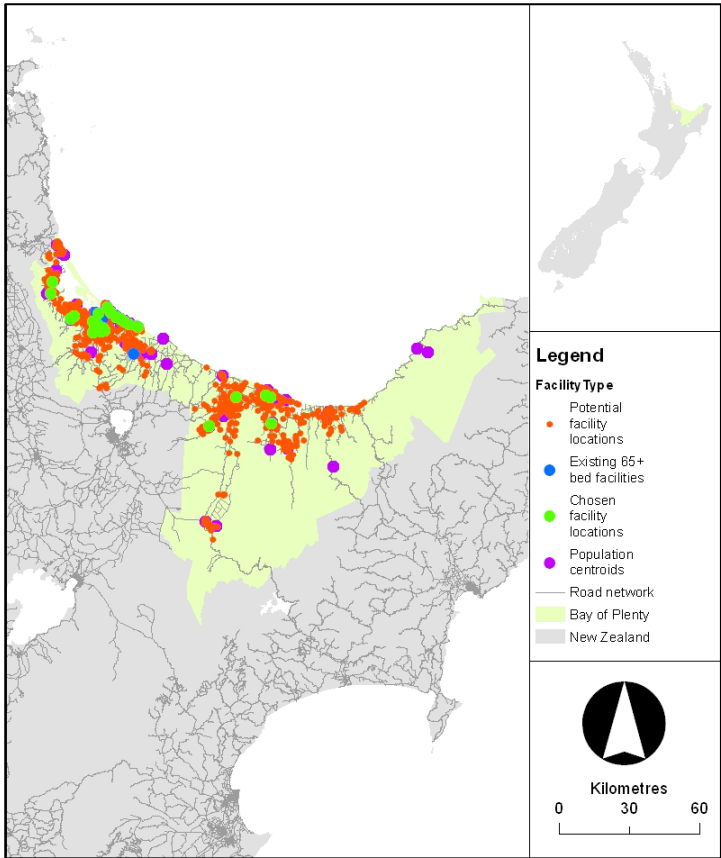


Figure 81: Bay of Plenty DHB. Site selection results, Scenario B

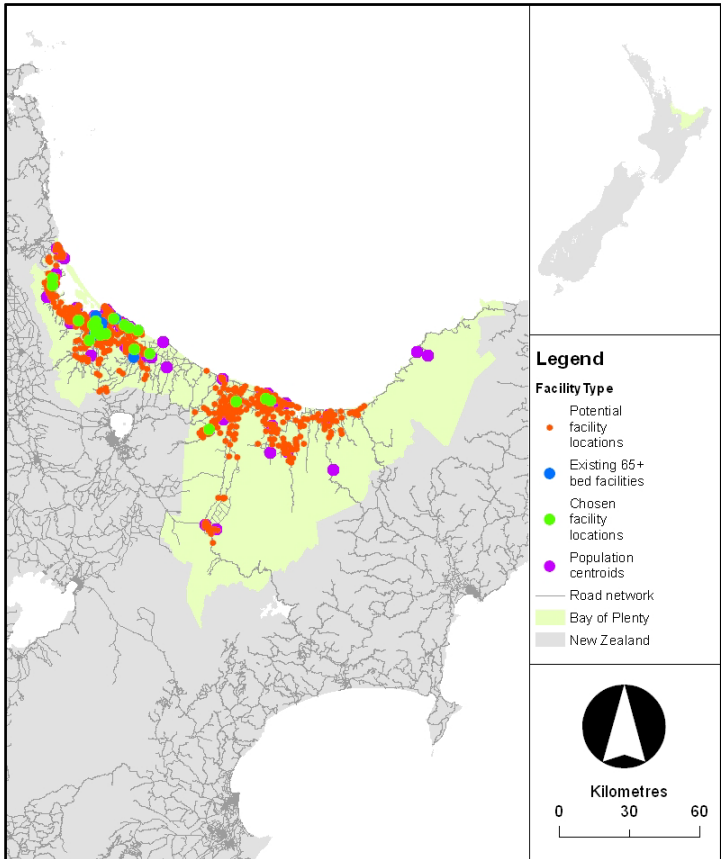


Figure 82: Lakes DHB. Site selection results, Scenario A

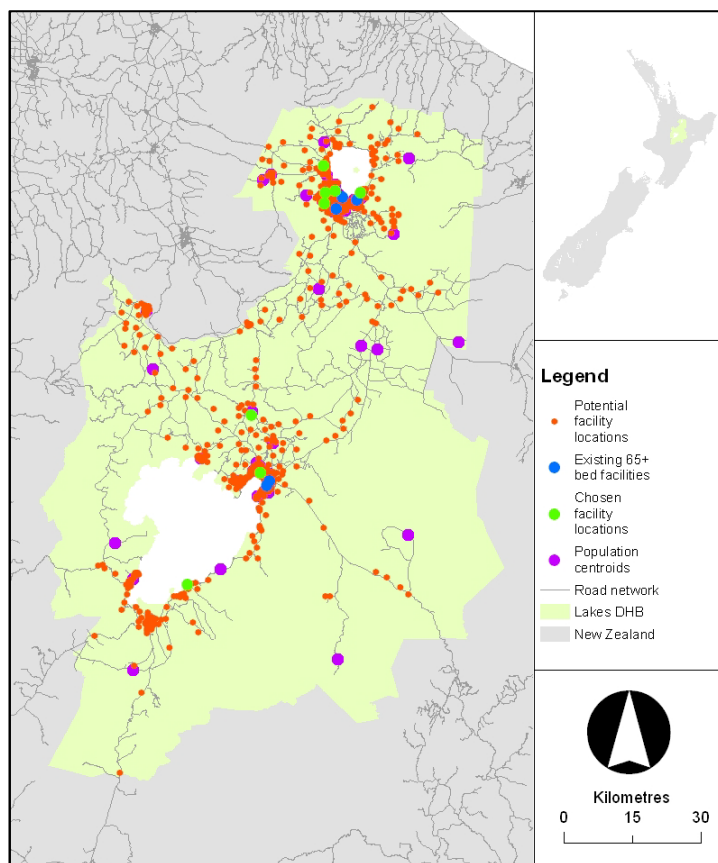


Figure 83: Lakes DHB. Site selection results, Scenario B

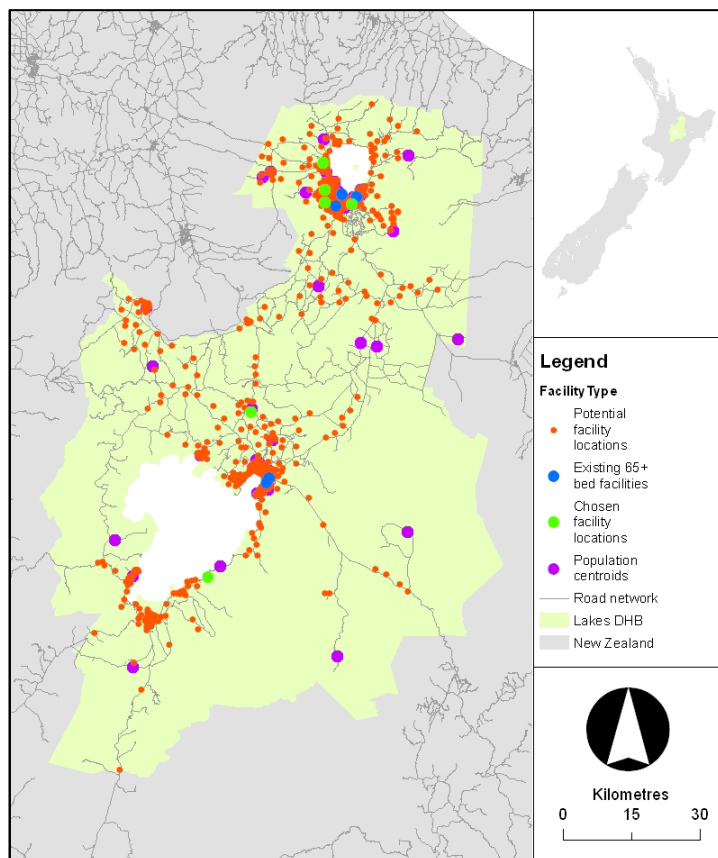




Figure 84: Tairāwhiti DHB. Site selection results, Scenario A

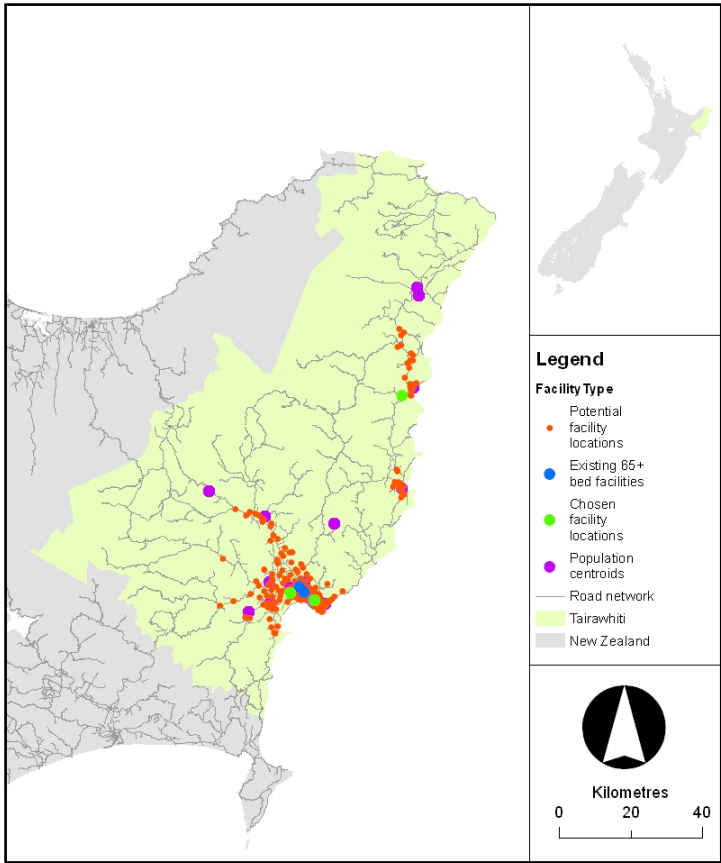


Figure 85: Tairāwhiti DHB. Site selection results, Scenario B

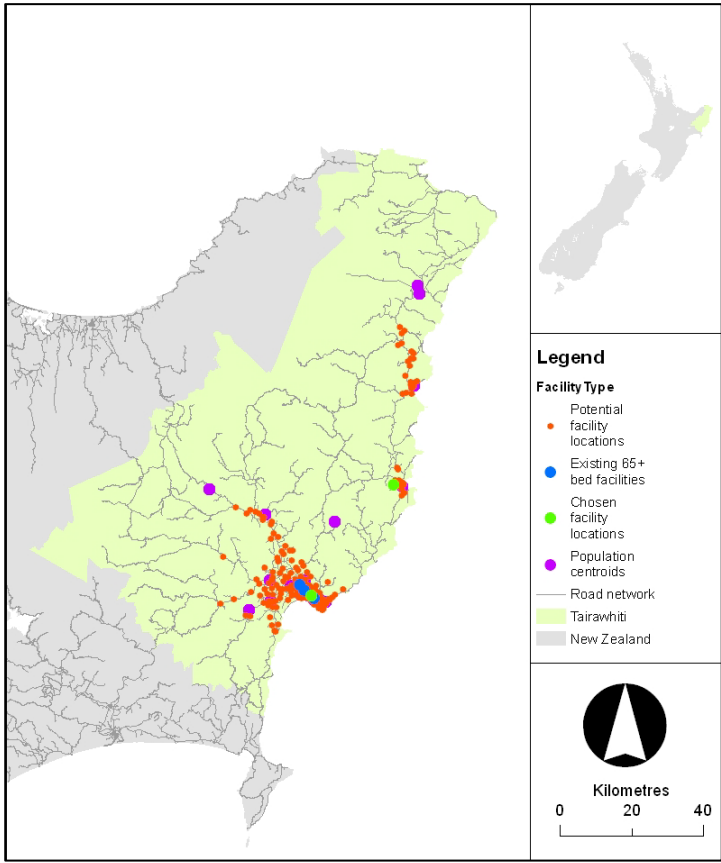


Figure 86: Taranaki DHB. Site selection results, Scenario A

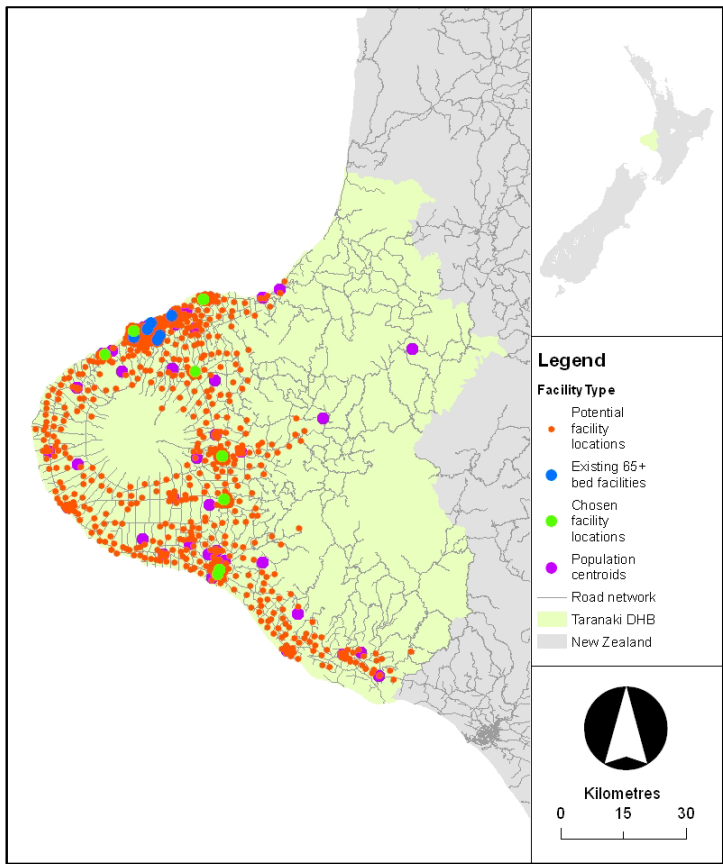


Figure 87: Taranaki DHB. Site selection results, Scenario B

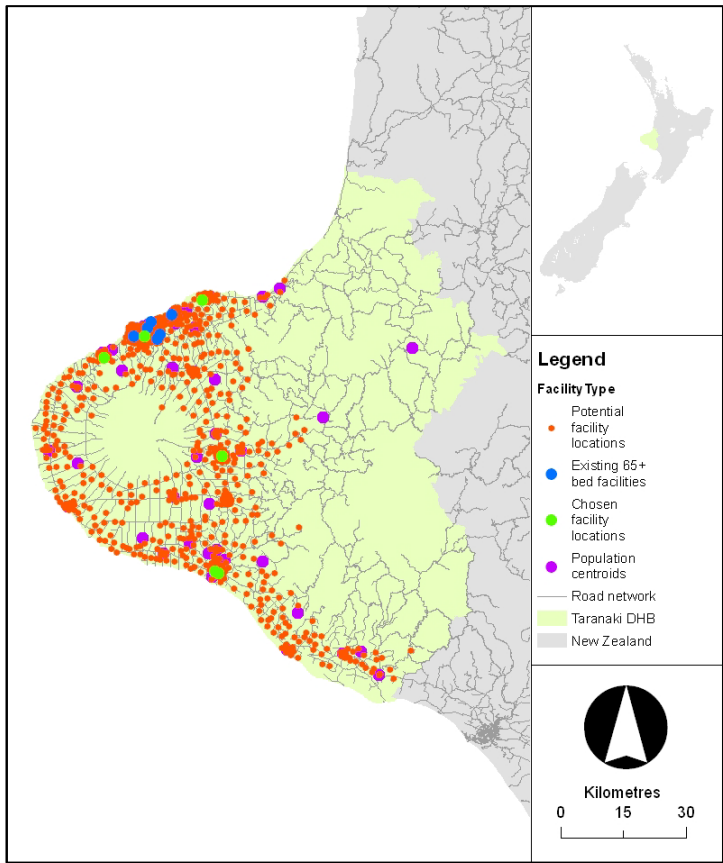


Figure 88: Hawke's Bay DHB. Site selection results, Scenario A

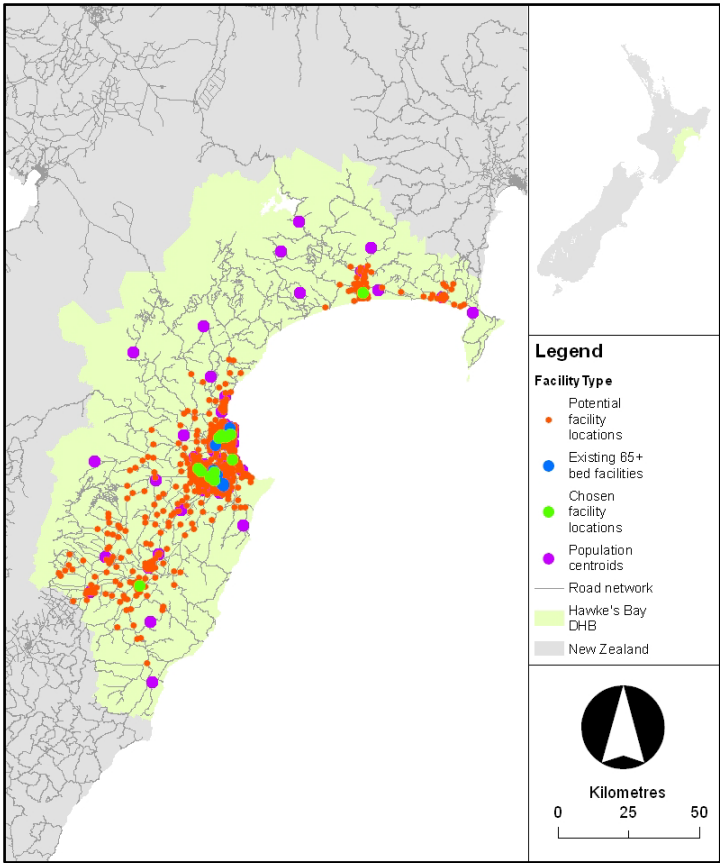


Figure 89: Hawke's Bay DHB. Site selection results, Scenario B

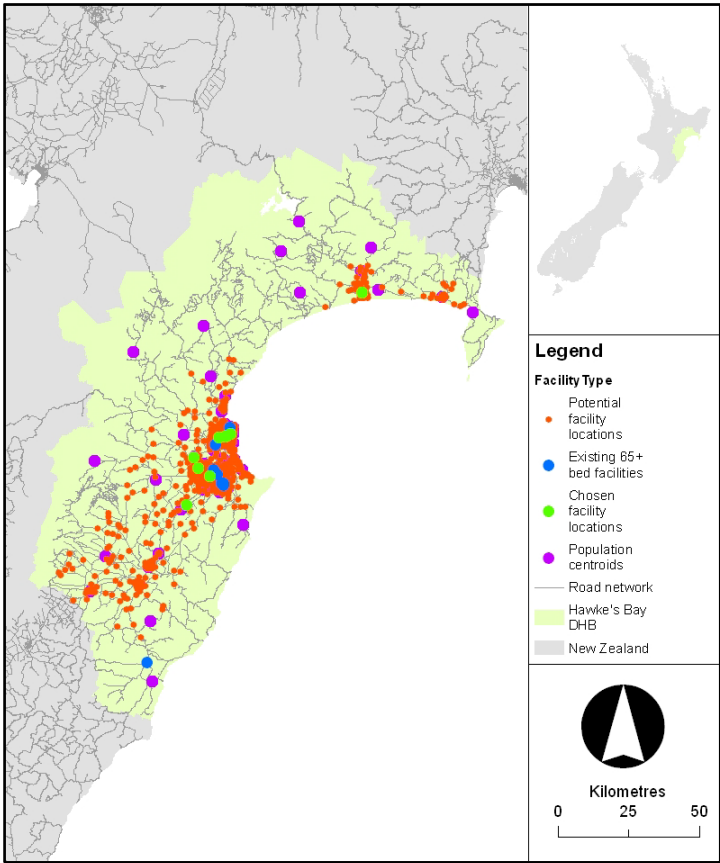




Figure 90: Whanganui DHB. Site selection results, Scenario A

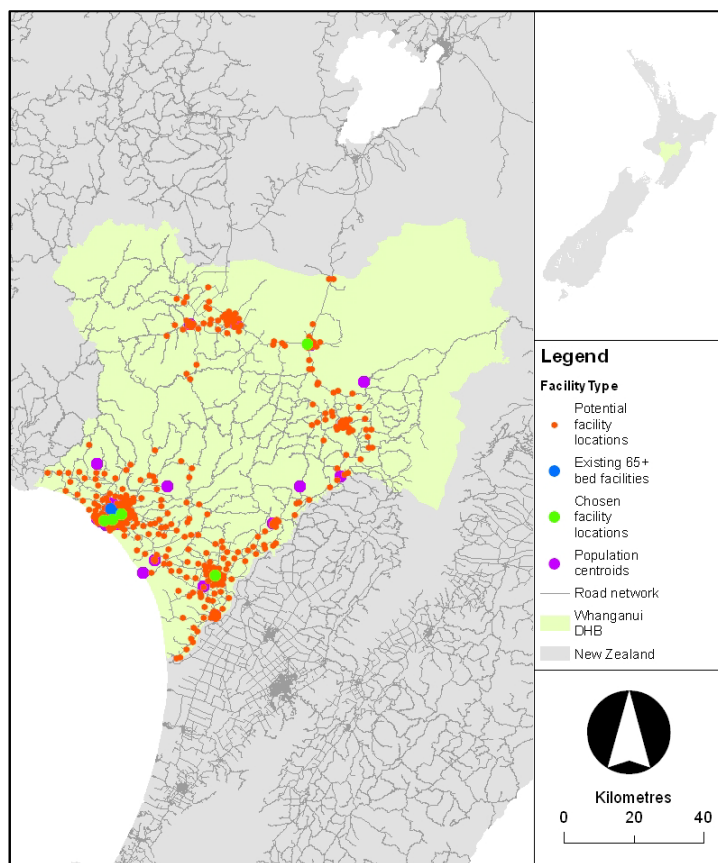


Figure 91: Whanganui DHB. Site selection results, Scenario B

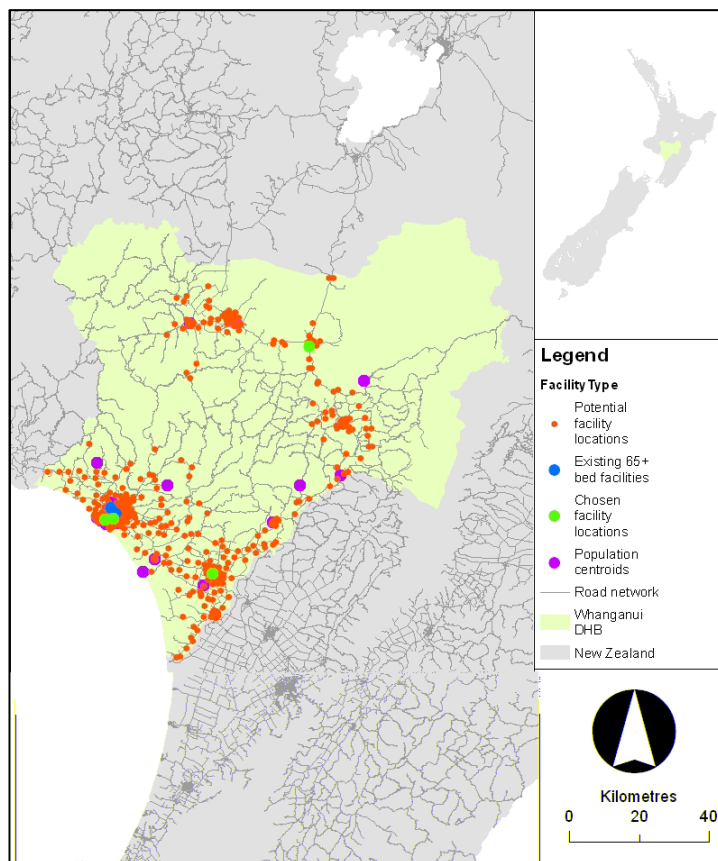


Figure 92: Mid Central DHB. Site selection results, Scenario A

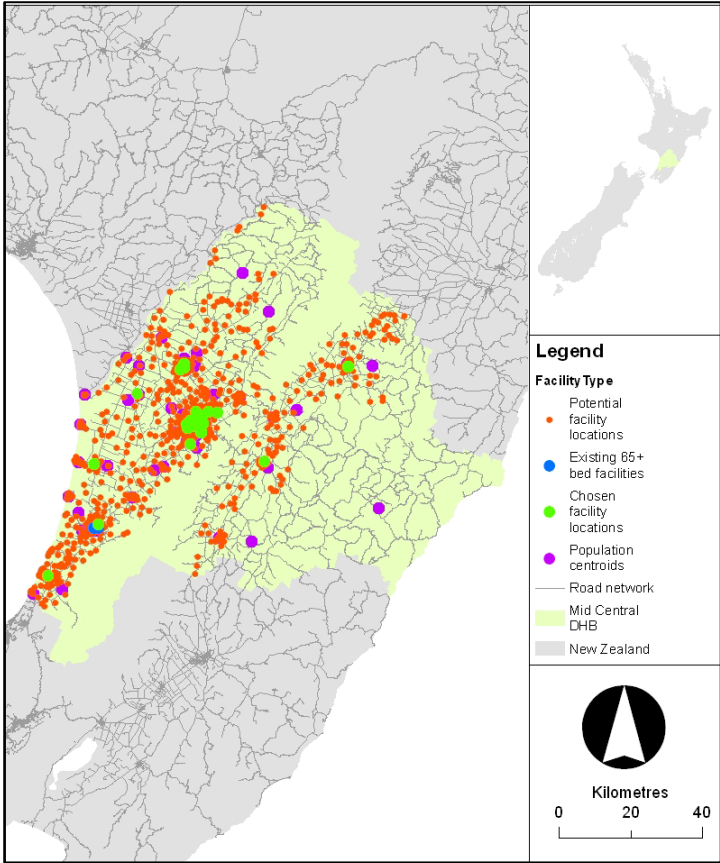


Figure 93: Mid Central DHB. Site selection results, Scenario B

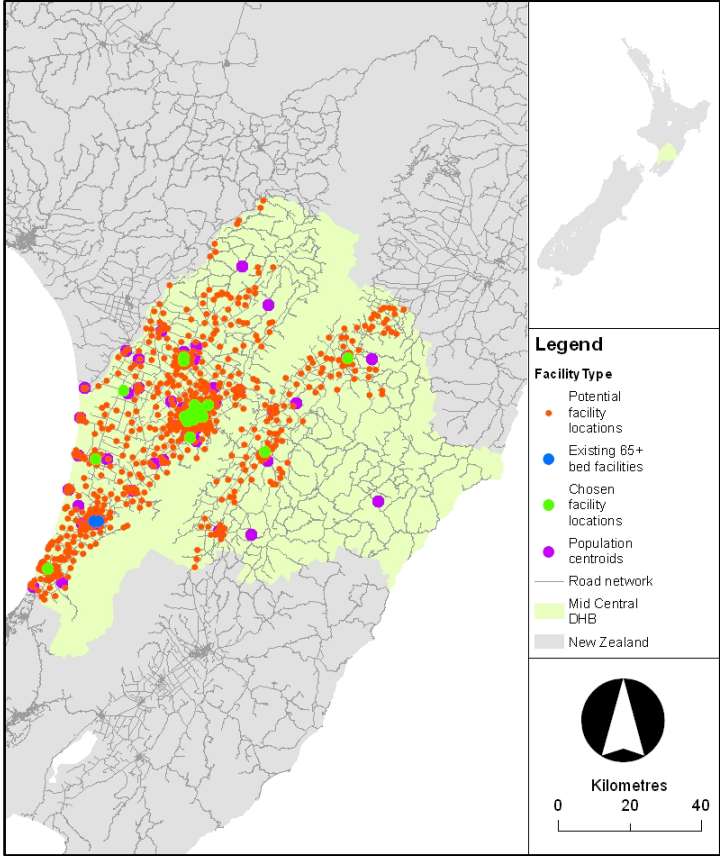


Figure 94: Capital and Coast DHB. Site selection results, Scenario A

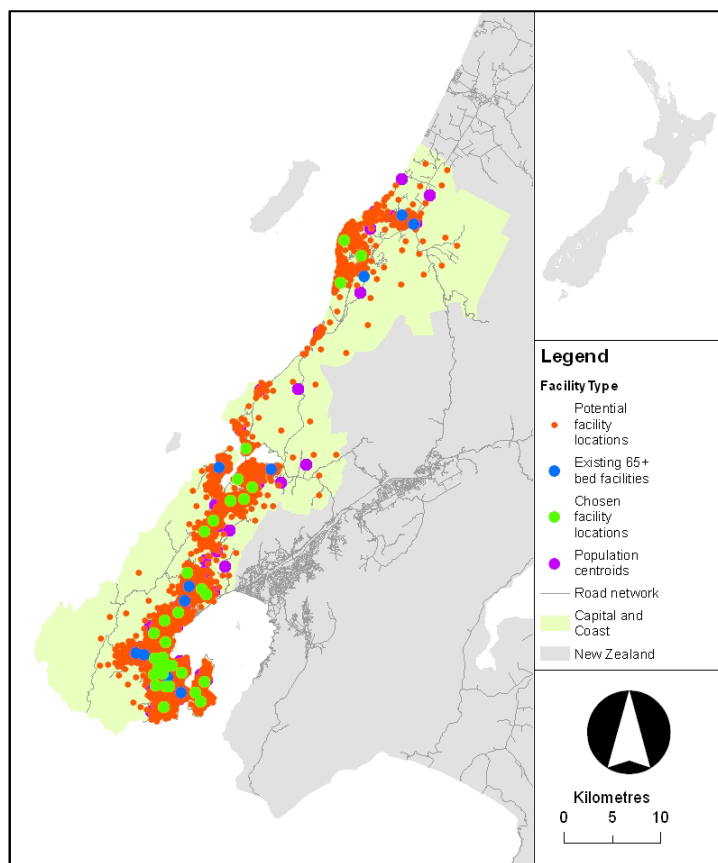


Figure 95: Capital and Coast DHB. Site selection results, Scenario B

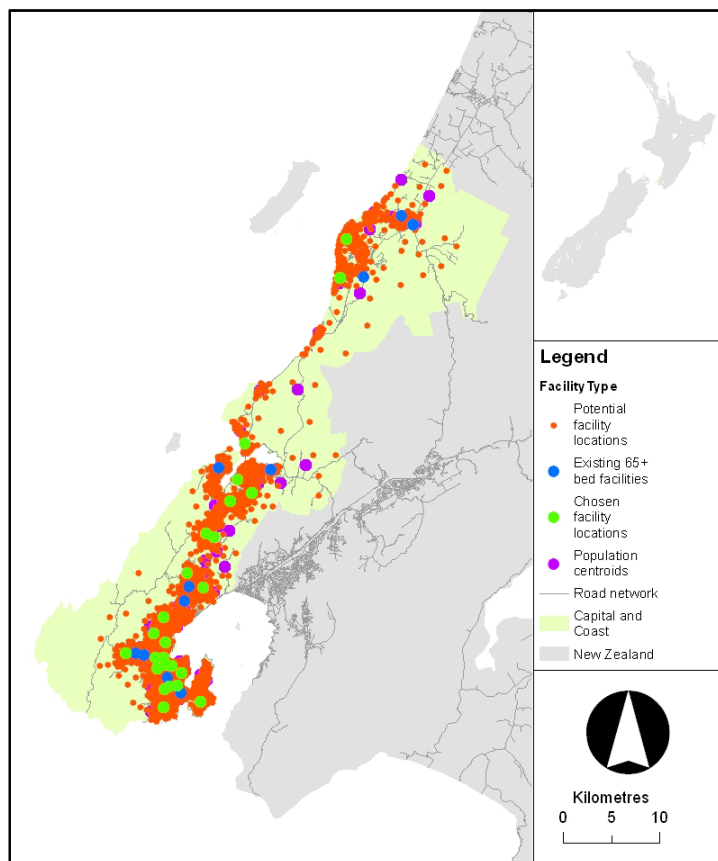


Figure 96: Hutt DHB. Site selection results, Scenario A

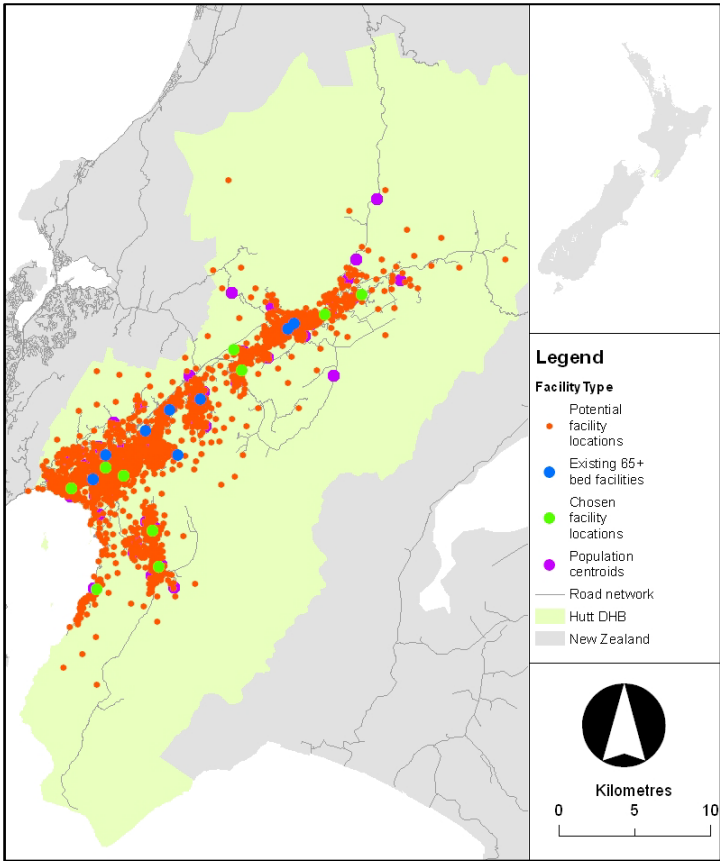


Figure 97: Hutt DHB. Site selection results, Scenario B

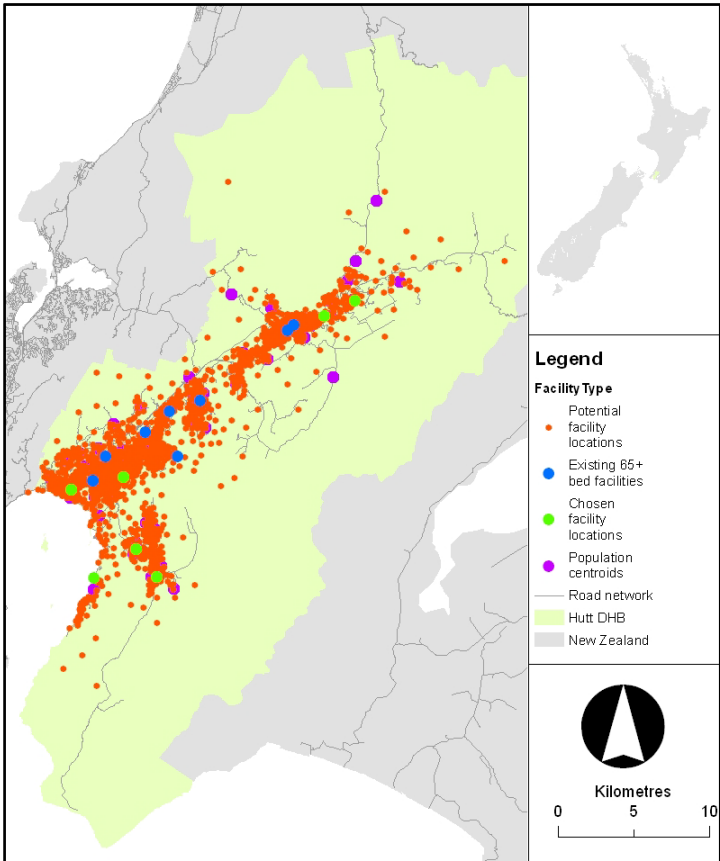


Figure 98: Wairarapa DHB. Site selection results, Scenario A

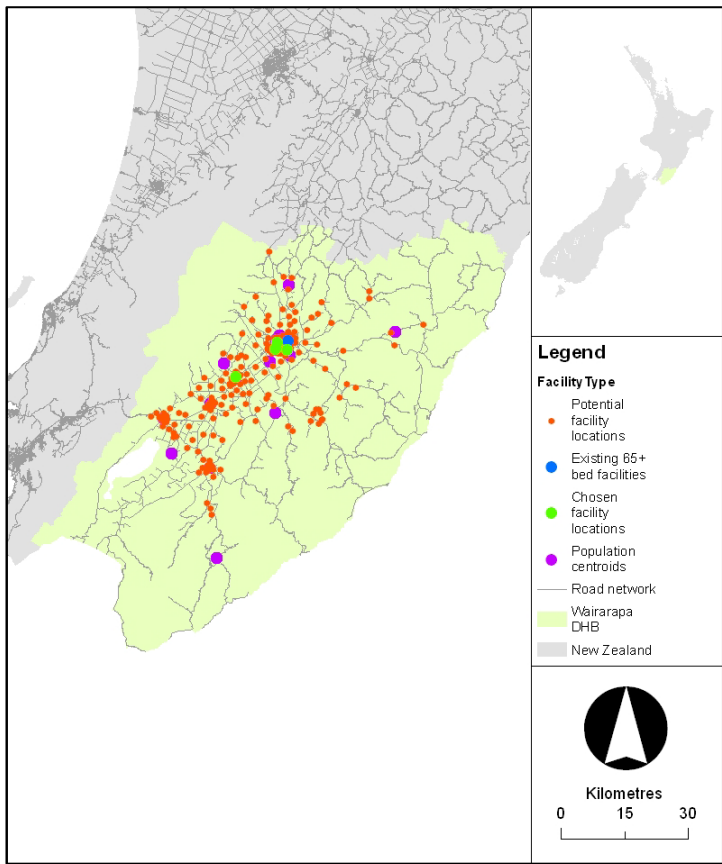


Figure 99: Wairarapa DHB. Site selection results, Scenario B

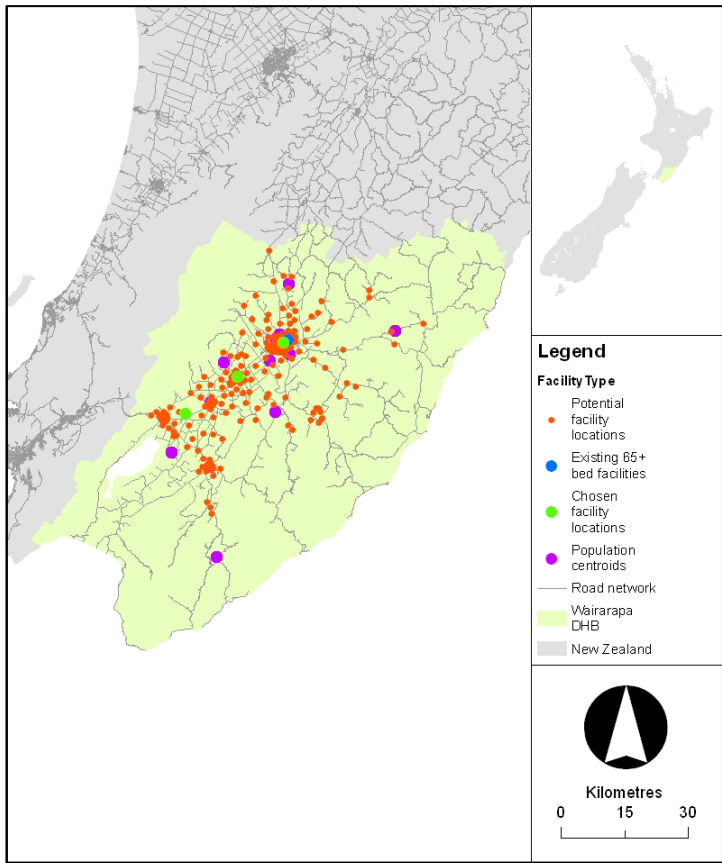


Figure 100: Nelson Marlborough DHB. Site selection results, Scenario A

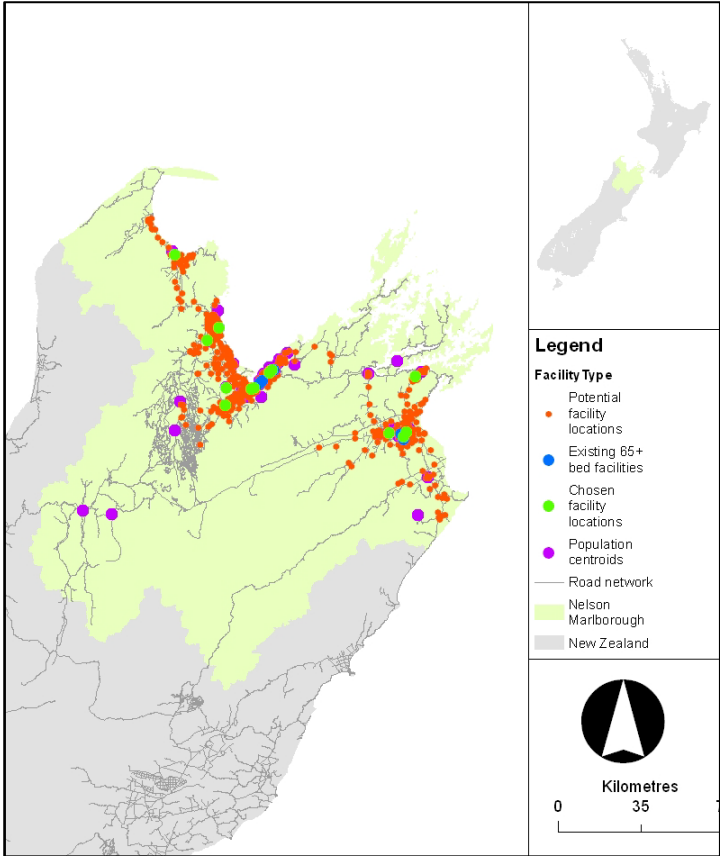


Figure 101: Nelson Marlborough DHB. Site selection results, Scenario B

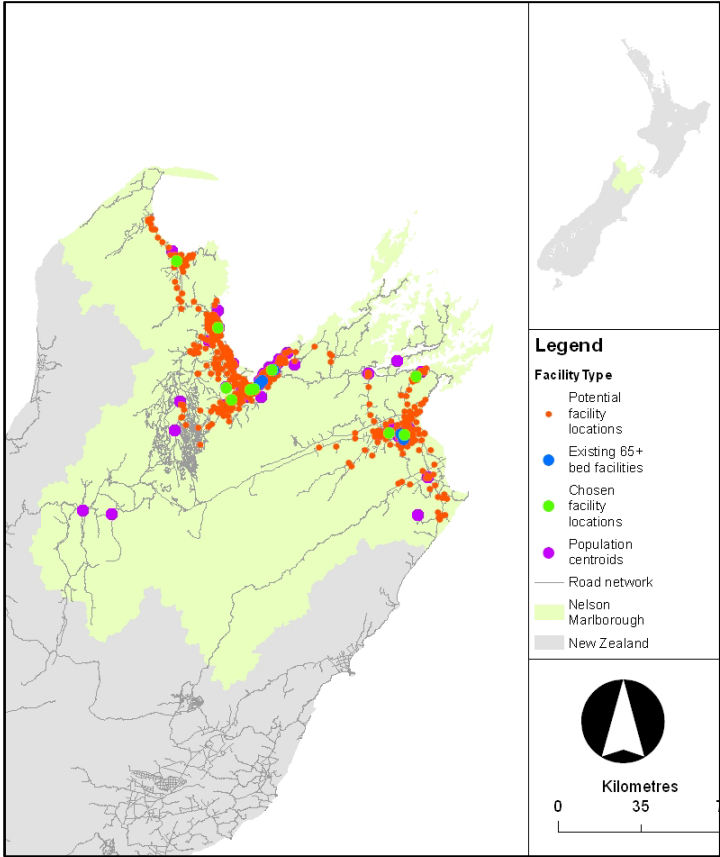




Figure 102: West Coast DHB. Site selection results, Scenario A

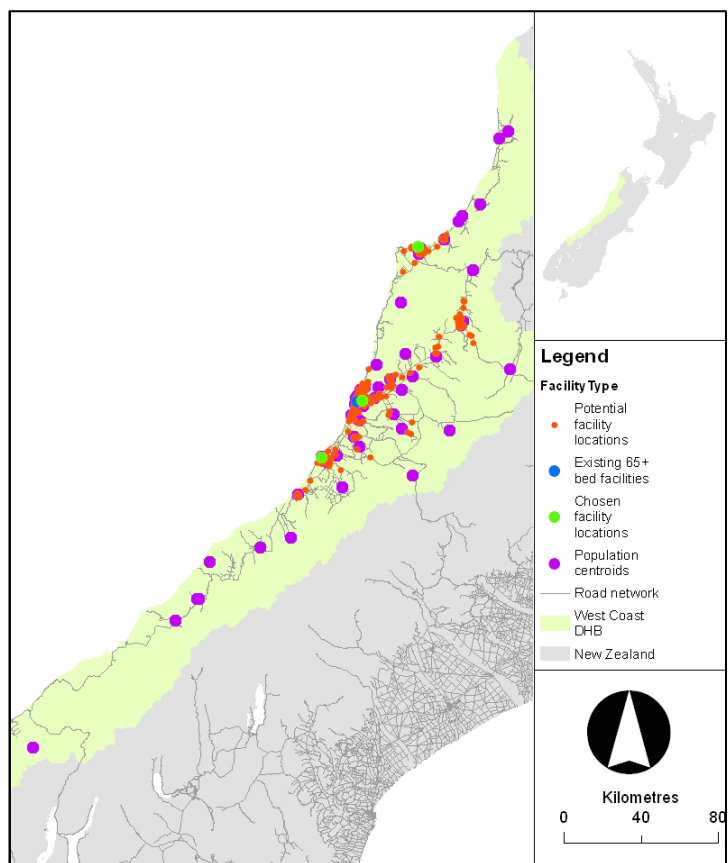


Figure 103: West Coast DHB. Site selection results, Scenario B

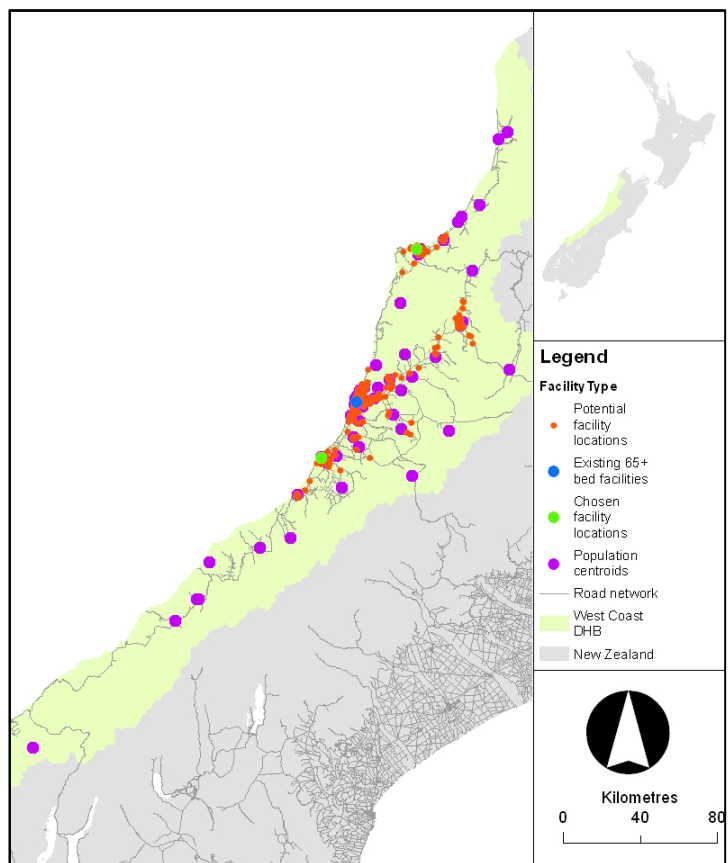


Figure 104: Canterbury DHB. Site selection results, Scenario A

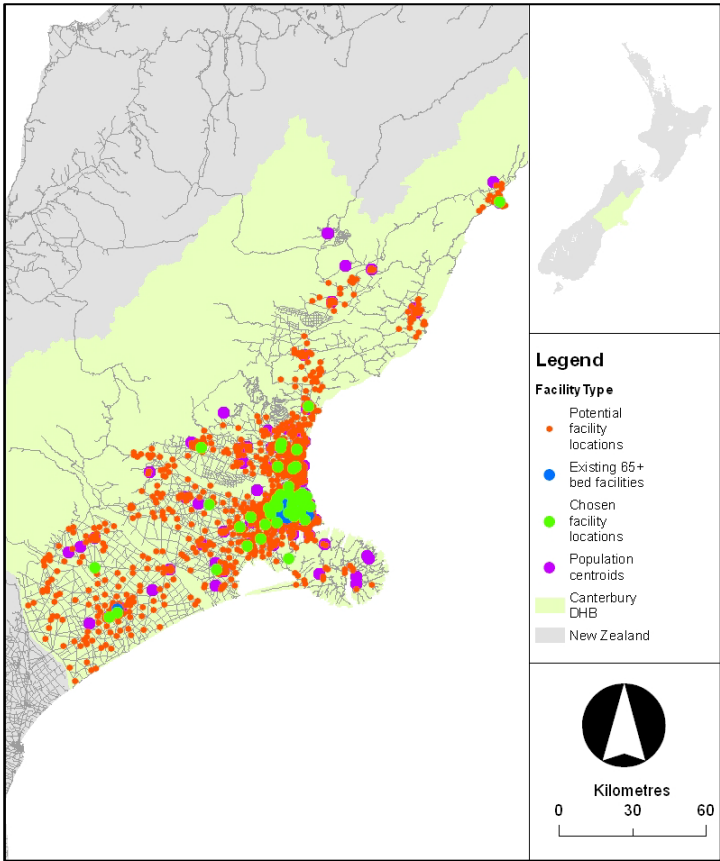


Figure 105: Canterbury DHB. Site selection results, Scenario B

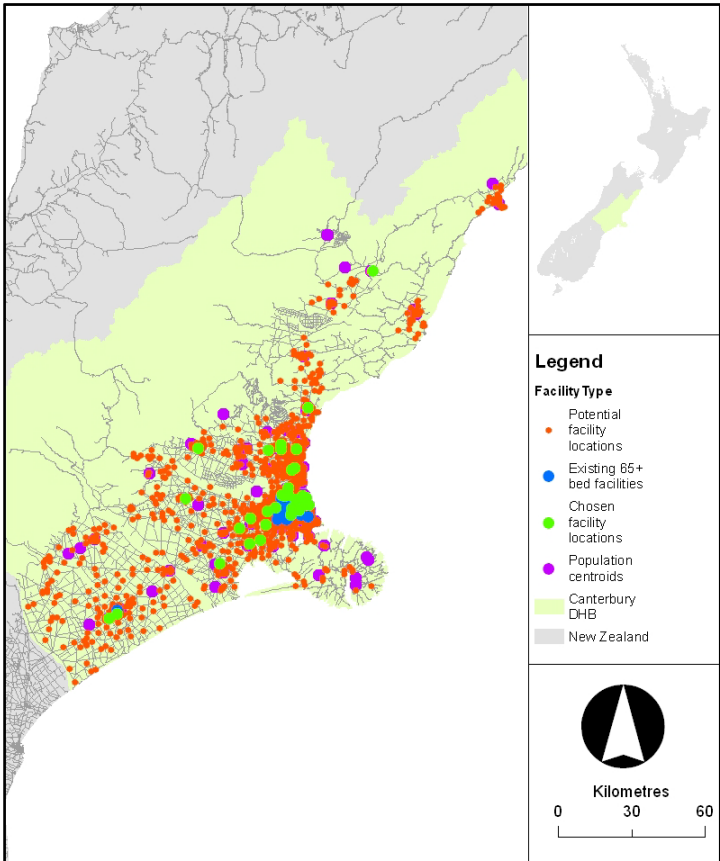




Figure 106: South Canterbury DHB. Site selection results, Scenario A

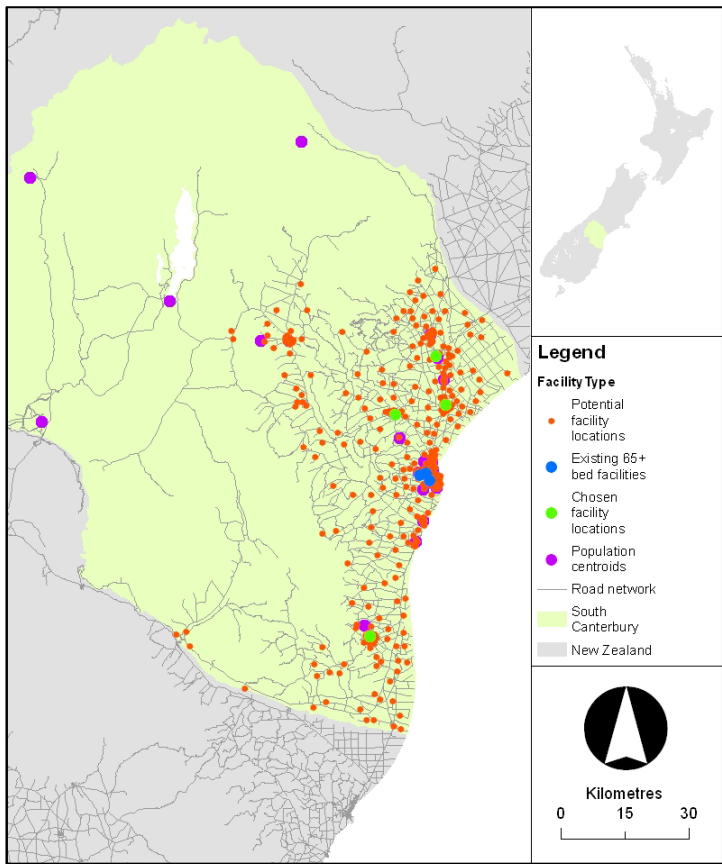


Figure 107: South Canterbury DHB. Site selection results, Scenario B

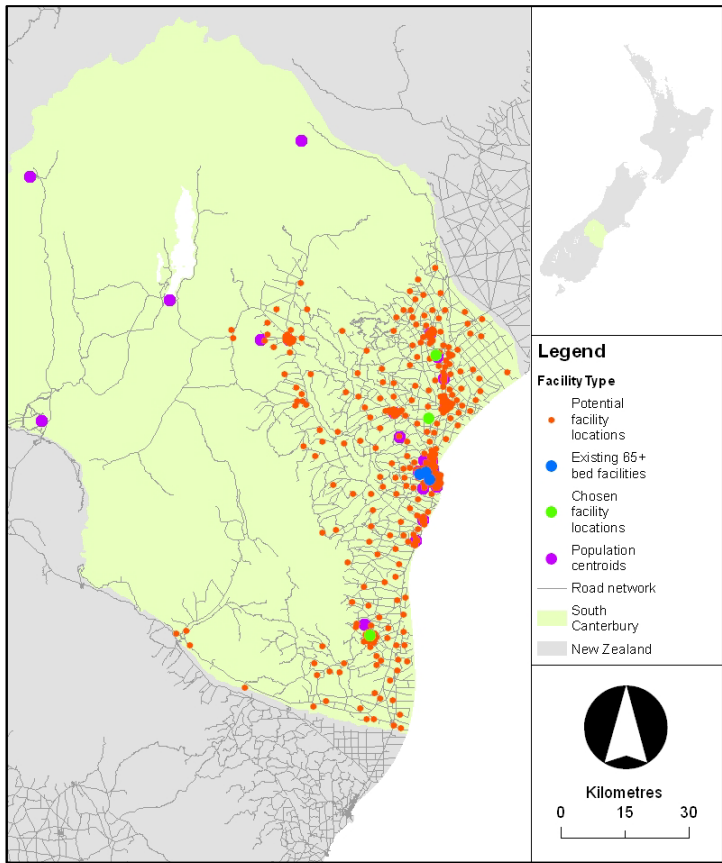


Figure 108: Southern DHB. Site selection results, Scenario A

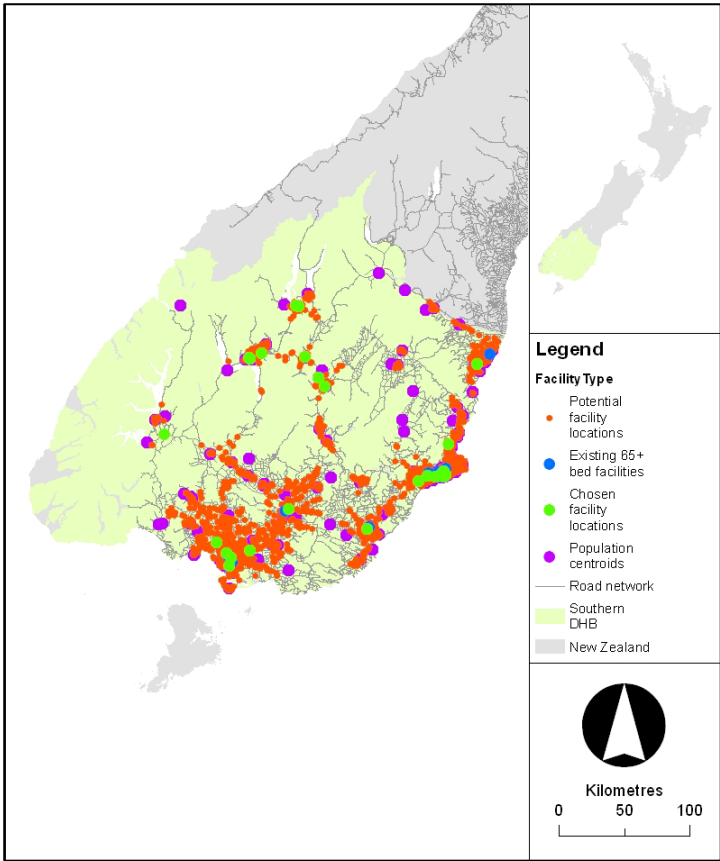
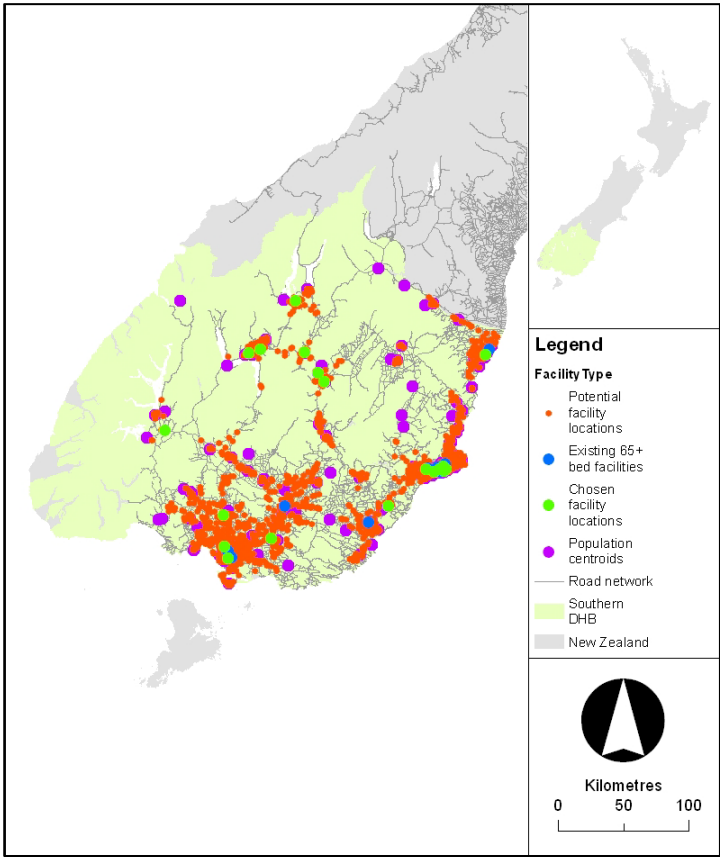


Figure 109: Southern DHB: . Site selection results, Scenario B





**Appendix six: Travel time to allocated facility by DHB and scenario**

Table 19: Summary – Travel times to allocated facility by DHB: Scenario A

Summary: Scenario A													
Name	Mean	Std dev	Skew	Min	p5	p10	p25	p50	p75	p90	p95	Max	
All DHBs	10.00	21.18	5.16	0.00	0.11	0.25	0.94	2.55	9.20	26.36	45.25	268.44	
Auckland	1.75	2.63	3.39	0.00	0.03	0.10	0.26	0.94	2.09	3.84	5.74	18.67	
Bay of Plenty	12.20	28.84	3.67	0.07	0.15	0.24	0.65	2.35	10.22	22.44	91.95	164.89	
Canterbury	6.45	12.27	3.41	0.00	0.24	0.40	1.04	2.03	5.33	15.82	37.45	89.85	
Capital and Coast	2.71	5.46	5.08	0.00	0.03	0.11	0.30	1.24	2.48	5.13	12.26	47.25	
Counties Manukau	6.47	9.88	2.05	0.00	0.02	0.14	0.46	1.83	8.74	19.80	31.68	48.54	
Hawke's Bay	10.88	18.52	3.07	0.04	0.09	0.24	0.99	3.28	10.66	35.91	53.53	120.12	
Hutt	2.51	2.69	2.29	0.11	0.19	0.58	0.92	1.49	3.19	6.21	8.21	14.38	
Lakes	10.56	15.57	2.02	0.05	0.22	0.52	1.37	2.58	15.77	29.19	50.70	78.33	
Midcentral	6.90	11.13	3.50	0.03	0.08	0.18	0.55	2.37	8.51	18.71	28.95	86.48	
Nelson Marlborough	11.95	24.10	3.82	0.01	0.22	0.66	1.25	2.82	10.52	32.91	46.51	157.41	
Northland	16.07	22.18	2.10	0.04	0.32	0.49	1.75	7.07	19.89	52.72	59.04	124.82	
South Canterbury	18.52	31.32	2.26	0.11	0.19	1.06	1.45	4.90	17.72	56.14	93.98	131.57	
Southern	17.20	29.28	3.67	0.06	0.42	1.04	2.15	6.72	18.77	45.21	72.77	224.53	
Tairāwhiti	15.84	26.37	2.69	0.95	1.05	1.32	1.67	3.89	20.43	33.43	77.04	126.27	
Taranaki	9.59	14.12	2.73	0.08	0.36	0.53	1.58	3.23	9.95	29.18	33.44	86.72	
Waikato	13.44	31.95	5.28	0.01	0.09	0.24	0.90	3.32	11.78	32.45	56.11	268.44	
Wairarapa	11.33	15.51	2.02	0.52	0.56	0.78	0.97	4.45	16.79	30.69	32.91	66.01	
Waitemata	4.15	7.02	3.70	0.00	0.04	0.10	0.48	1.69	4.77	9.82	14.12	74.33	
West Coast	31.18	38.36	2.81	0.54	1.72	2.44	6.03	18.65	47.03	76.17	92.90	241.54	
Whanganui	8.40	11.81	2.01	0.02	0.33	0.78	1.43	2.30	14.37	23.56	30.88	60.20	

Table 20: Summary - Travel times to allocated facility by DHB: Scenario B

Summary: Scenario B													
Name	Mean	Std dev	Skew	Min	p5	p10	p25	p50	p75	p90	p95	Max	
All DHBs	9.93	19.00	4.19	0.00	0.18	0.38	1.21	2.86	9.47	26.16	48.82	218.15	
Auckland	2.45	3.61	2.74	0.03	0.06	0.17	0.38	1.36	2.39	5.98	11.47	21.21	
Bay of Plenty	11.89	29.22	3.92	0.00	0.12	0.23	0.86	2.57	8.38	21.70	84.24	189.63	
Canterbury	6.77	12.35	3.49	0.04	0.29	0.53	1.20	2.10	5.84	16.37	33.46	97.44	
Capital and Coast	2.60	3.39	3.25	0.00	0.05	0.17	0.62	1.45	3.27	6.49	9.51	37.07	
Counties Manukau	3.66	5.06	3.44	0.00	0.11	0.19	0.79	1.97	4.46	8.97	13.16	39.59	
Hawke's Bay	11.52	19.58	3.38	0.04	0.16	0.44	1.37	3.55	12.28	37.62	41.61	122.93	
Hutt	3.05	3.85	3.18	0.05	0.26	0.58	1.03	1.58	3.95	7.10	10.05	25.55	
Lakes	10.97	14.90	2.11	0.05	0.36	1.13	1.66	3.39	17.19	29.22	44.92	89.07	
Midcentral	7.21	11.48	2.94	0.06	0.18	0.26	1.11	2.56	7.97	18.20	30.07	86.48	
Nelson Marlborough	15.44	30.98	3.53	0.07	0.48	0.85	1.67	3.49	11.41	39.71	76.54	191.35	
Northland	13.50	17.68	2.59	0.04	0.32	0.76	2.18	7.57	18.01	35.81	50.88	112.86	
South Canterbury	16.10	29.67	2.63	0.19	1.06	1.22	2.00	5.10	7.71	65.23	93.98	131.57	
Southern	15.69	20.44	2.07	0.06	0.65	1.04	2.26	6.17	22.50	49.65	59.49	120.93	
Tairāwhiti	21.28	30.90	1.55	1.05	1.14	1.14	1.42	3.89	29.70	59.66	88.13	133.29	
Taranaki	11.55	16.59	2.51	0.08	0.63	0.88	1.62	3.97	15.53	30.53	45.21	91.64	
Waikato	11.51	20.36	3.66	0.01	0.13	0.31	1.15	3.92	12.74	26.25	57.98	171.94	
Wairarapa	8.70	9.92	2.05	0.29	0.66	0.69	1.80	4.57	11.53	22.25	25.38	42.87	
Waitemata	5.04	9.01	4.02	0.00	0.09	0.18	0.86	1.87	4.88	13.87	18.29	77.70	
West Coast	37.55	38.94	2.11	0.54	1.86	2.98	7.17	22.64	51.92	85.10	92.90	218.15	
Whanganui	8.88	13.11	2.85	0.33	0.64	0.88	1.40	3.30	15.18	24.59	30.39	78.71	