A GIS BASED INVESTIGATION OF SPATIAL ACCESSIBILITY TO HEALTH CARE FACILITIES BY LOCAL COMMUNITIES WITHIN AN URBAN FRINGE AREA OF MELBOURNE.

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for the degree of Master of Applied Science

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DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Salahuddin Ahmad

ABSTRACT

A GIS BASED INVESTIGATION OF SPATIAL ACCESSIBILITY TO HEALTH CARE FACILITIES BY LOCAL COMMUNITIES WITHIN AN URBAN FRINGE AREA IN AUSTRALIA

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Adequate and equitable access to health care facilities by local communities in urban areas is an important issue of human service provision to both public policy makers and urban planners. Equitable and easy access to health care facilities is often considered one of the main objectives of many health care systems. Due to spatial variations in population distribution, transportation infrastructure as well as distribution of health care facilities, there exists spatial variation in accessibility to the health care facilities and locations where accessibility to health care facilities is poor. This study aims to use a GIS based case study approach and “spatial accessibility” measures, derived from fine spatial resolution datasets, to characterize and reveal spatial variations in access to health care facilities and identify disadvantaged locations / local communities in a selected urban fringe area in Melbourne, Australia.

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DEDICATION

To Noman

One day I hope you will appreciate the sacrifice I and your mother have made for you to grow-up and prosper in this county. This was the first step in a long journey to provide you with a better life.

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Chapter 1 Introduction

1.1 Introduction

It is a fundamental human right to have access to health care services when needed. It is desirable for a government to ensure high quality provision and equal and easy access to fundamental health care services to all citizens. Varying spatial distribution of the population, health care facilities and transportation infrastructure in an area often lead to spatial variations in accessibility to health care facilities, which in turn will result in disadvantaged locations and communities having poor spatial accessibility to needed health care facilities.

Adequate, equitable and easy access to health care facilities by local communities in a specified geographic area is an important issue of human service provision to the individuals living in that area. It is also a challenging issue for both public policy makers (Wang and Luo 2005; Burns and Inglis 2007) and urban planners (Geertman and Van Eck 1995; Hewko 2001). In many health care systems, adequate, equitable and easy access to health care facilities is often considered one of the main objectives (Powell and Exworthy 2003). To ensure equal and easy access it is essential to ensure that the population, health care facilities and the transportation infrastructure are positioned in a manner that facilitates high spatial accessibility. There are many different conceptualizations of accessibility to health care facilities, and many different measures of accessibility have been proposed and used in the literature (Hewko 2001; Talen and Anselin 1998). Accessibility to a destination e.g. health care facility via a specified transportation network has been measured by physical distance (Ingram 1971; Gugliardo 2004), travel time (Hansen 1959; Ingram 1971; Iversen and Kopperud 2005), or even travel cost (Ingram 1971; Cho 1998; Lovett 2002).

A comprehensive literature review conducted for this study (see Chapter 2) reveals that a few studies have been conducted in the Melbourne Metropolitan area for the characterization of accessibility to health care facilities and for identifying locations where accessibility to health care facilities is relatively poor (Bamford et al 1999, Randolph and Holloway 2005, Burns and Inglis 2007, Engels and Liu 2011, Liu and Engels 2012). The spatial resolution at which those studies have undertaken, however, are relatively coarse to allow accurate measurement of travel distance, travel time or travel cost between health care facilities and the locations of the populations. Therefore, their results have not been able to reveal at fine resolution the spatial variations in spatial accessibility to health care facilities.

It is important to measure spatial accessibility at fine spatial resolution (Ahmad et al. 2009). Therefore, this study has been focused on local communities residing in an urban fringe area, and the study is designed in such a way so that it enables the use of high spatial resolution data sets and Geographic Information System (GIS) based spatial analysis and spatial statistical measures, and seeks to uncover spatial variation in accessibility to health care facilities at fine spatial resolution (e.g. at the Mesh Block level). Health care facilities include only locations where health care service providers (e.g. Pharmacists, General Practitioners / Surgeons clinic and dentist) conduct their face-to-face health care service to site-visiting health care users. A local community refers to the residents confined within a

Mesh Block (MB) or a Census Collector District (CCD), as defined by the Australian Bureau of Statistics (ABS). An urban fringe area refers to a local government area at the edge of a large metropolitan area which in this case is Melbourne, Victoria, Australia.

1.2 Research objectives and research questions

This study aims to develop a GIS based approach to the characterization of spatial accessibility to health care facilities by local communities resided within an urban fringe area of Australia. It is assumed that there exist spatial variations in the spatial distribution of population, health care facilities, and transportation infrastructure, that together impact on the overall spatial accessibility to health care facilities. It is also assumed that there exist localities in the case study area where spatial accessibility to health care facilities is relatively poor. Therefore, the research objectives are:

- to characterize spatial variation in access to health care facilities in terms of the spatial distributions of potential users, health care facilities, and transportation infrastructure;
- to identify local communities where spatial accessibility to health care facilities is relatively poor;
- to achieve the above objectives for a selected case study area, i.e. the Cardinia Shire in the Melbourne urban fringe area, at a fine spatial resolution using a GIS based analytical approach.

Attempts have been made to present appropriate answer to these research objectives in Chapter 4 and 5. Section 4.3 presents the spatial distribution and characteristics of the potential users of the health care facilities, section 4.4 presents the locational analysis of the health care facilities and section 4.5 presents the positioning of the transportation infrastructure and their characteristics. Characterization of spatial accessibility to health care facilities and identification local communities where spatial accessibility to health care facilities is relatively poor has been presented in section 5.2 and 5.4. A GIS based analytical method has been presented and discussed in Chapter 3.

A GIS-based methodology derives the specified outputs by means of GIS-based spatial data manipulations and spatial analyses, which are supported by a carefully built GIS-based spatial database. Building a GIS-based spatial database to develop procedures for spatial data manipulations and spatial analyses includes the identification and collection of the required spatial data and relevant tabular data including census data; building a geodatabase and organizing spatial data and attributes; developing a geoprocessing framework and analytical procedures for the manipulation of spatial data and attribute data. GIS based spatial analysis includes measuring spatial pattern of the case study population, health care facilities and transportation network; measuring travel distance and travel time between locations of health care facilities and their user communities via the road network and measuring spatial association between available health care facilities and health care user community.

In this study, spatial accessibility is conceptualized as being influenced by the characteristics of the service users, the service provision facilities and the conditions of the transportation network linking the users and the providers of the health care services (Section 3.2); spatial accessibility is measured by the travel distance and travel time that local communities need to undertake from their residential locations (as represented by the centroids of their residential MBs) to locations of selected health care facilities (usually the nearest or the most attractive), in terms of physical distance (e.g. shortest Euclidean distance or network distance), (shortest) travel time, or (least) travel cost (Section 3.7.2 and Section 5.2); spatial variations in accessibility to heath care facilities are measured by the spatial distribution of travel distance and travel time as well as travel distance based accessibility index (Section 3.7.2 and Section 5.2.3); and spatial association and spatial statistical methods are applied on accessibility index and census dataset to identify clusters of high or low accessibility in terms of travel distance, travel time, and population counts in each MB (Section 3.7.3 and Section 5.4).

To achieve the research objectives stated above, the following three research questions have been developed:

1. What are the characteristics in the spatial distribution of population, health care facilities and transportation infrastructure in the selected case study area?
2. What are the characteristics in spatial accessibility to health care facilities by local communities in the selected case study area?
3. How to identify the spatial clusters of disadvantaged locations / local communities in the selected case study area at fine spatial resolution using a GIS-based approach?

Similar to the research objectives, these research questions have also been answered throughout the thesis. Chapter 4 presents the distribution and characteristics of the potential users of the health care facilities, distribution of the health care facilities and transportation infrastructure and their characteristics. So, research question 1 has been answered in Chapter 4. Research question 2 is about identifying the spatial variation and spatial pattern in access to health care facilities in selected case study area has been discussed in Chapter 5. Research question 3 is about the GIS based analytical approach to the identification of spatial variation and disadvantaged locations at fine spatial resolution have been discussed in Chapter 3 and Chapter 5.

1.3 Outline of the thesis

In order to address the research objectives and answer to the research questions stated in Section 1.2, this thesis has adopted in a systematic structure as outline below (see Figure 1-1): Chapter 1 introduces the study with the research objectives and research questions. Chapter 2 summarizes the literature review, focusing on some key terms relevant to this study, including the notions of access, accessibility and spatial accessibility to the health care facilities and measures of accessibility, spatial patterns and spatial associations in demand for and accessibility to health care facilities. Chapter 3 outlines the research methodology developed for this study, with a discussion on data collection, preparation and analytical procedures. Chapter 4 describes the study area in terms of location, land use type, settlement and other general characteristics of the Cardinia Shire, as well as some considerations on the Shire's demographics, health care facilities, and transportation infrastructure. Chapter 5 presents the research outcomes of measuring spatial accessibility to health care facilities in terms of proximity and travel time between centroids of local communities and locations of health care facilities, service catchments and accessibility index. The location where accessibility to health care facilities is deemed to be low has also been identified and presented in cluster maps. Finally, in Chapter 6 the main research findings made from this analysis are discussed and assessed, followed by some recommendations for further improvement and researches.

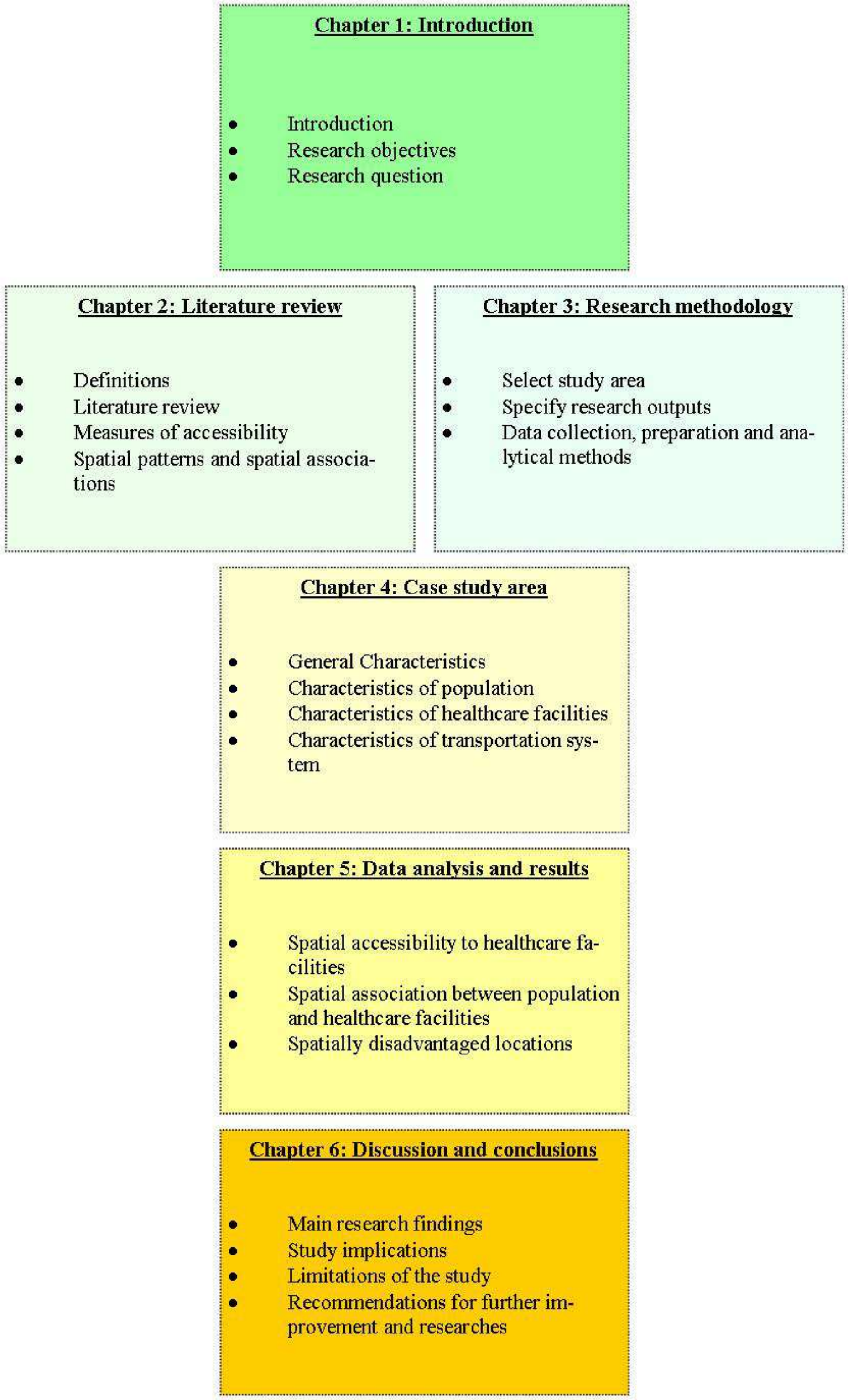


Figure 1-1 Organization of the thesis

Chapter 2 Literature Review

2.1 Introduction

The purpose of this chapter is to review the literature in order to establish what other relevant researches have been done to date. In the literatures, many approaches have been used to define and measure the key concepts of access, accessibility and spatial accessibility (i.e. Cameron, 1995; Ansari, 2007). The terms access, accessibility and spatial accessibility are related but very different concepts (Khan 1992; Cameron 1995) even though in the health care literature these terms are often used interchangeably. The following sections attempt to clarify the key terms access, accessibility and spatial accessibility within the context of the work that is presented in this study.

2.2 Access

Access can be described as the 'degree of fit' between users and a service. The 'degree of fit' might be influenced by the availability, accessibility, accommodation, affordability and acceptability of a service (Penchansky and Thomas, 1981). Furthermore, access is linked with the demographic, socio-economic and cultural characteristics of the population, locations of the health care facilities and of the transportation network. In other words, access is patterned both spatially and socially (Field et al 2004). Spatially, the more resources that are provided into an area for use the greater the likelihood that people will use those resources and live in that surroundings. Access to an existing resource or facility (e.g. a hospital or a road network) is generally understood as the capacity of an individual to obtain a service when it is needed (Schneider & Symons, 1971). The meaning of access, however, can vary among researchers, policy makers, politicians and public, due to differences in their education history, workplace condition, and cultural context.

Over the last four decades, scholars focusing on access issue generally agree that 'access' is not a well defined term (Aday and Andersen 1974, Penchansky and Thomas 1981). The literature also suggests the term 'access' cannot be understood on its own but rather, it must be differentiated from other closely related terms, which are often used interchangeably with the term access, including accessibility, availability, affordably, barrier, right of entry, right to use, mobility, and level of permission (Bagheri, Benwell et al. 2005; Guagliardo et al 2004). Penchansky and Thomas (1981) distinguished two aspects of access, spatial and socio-economic, and described the spatial aspect of access in terms of availability, accessibility and accommodation and the socio-economic aspect of access in terms of affordability and acceptability (Figure 2-1). Bagheri, Benwell et al. (2005) and Guagliardo et al (2004) only consider the first two dimensions as the spatial components for spatial accessibility. Khan (2002) described access in terms of both spatial (geographic) and aspatial qualities. In the literature, other terms such as resource allocation, equity, and social justice are also frequently used by social scientists and planners. These terms help the planners and policy makers to decide for whom the benefits are to be distributed, or "who gets what" and "who pays" (Talen, 1998). To add to the complexity of the concept of access, the terms access and accessibility are often used indiscriminately and are often misunderstood, poorly defined and poorly measured (Geurs and Wee, 2004).

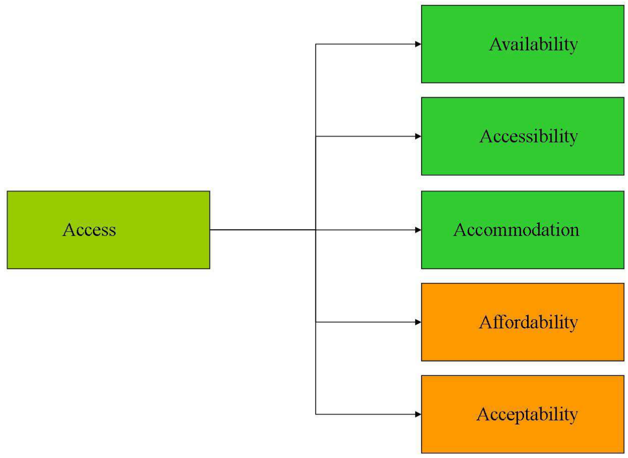


Figure 2-1 Classification of accessibility (adapted from Penchansky and Thomas, 1981)

Access is quite a complex term to define and it becomes more complex when the measure of access is not simply the presence of a health care facility, as the presence of service does not ensure the utilization of these facilities in relation to need and health care services users and service provider professionals evaluate "need" differently (Donabedian, 1972). Penchansky and Thomas (1981) observed that access is most frequently viewed as a concept that somehow relates to the consumers' ability or willingness to use health care services, and therefore should consider the personal, financial and organizational barriers to health care service utilization. In contrast, Mooney (1983) argued that access is a question of supply; whereas the utilization is a function of both supply and demand. Equity of access is purely a supply side consideration, in the sense that equal services are made available to patients who have equal health concern (Goddard and Smith 2001).

2.3 Accessibility

According to Vickerman (1974), accessibility is a combination of two elements: locations on a surface relative to suitable destinations, and the characteristics of transportation networks linking points on that surface. Accessibility defined as such is similar to the notion of access, as it has a number of spatial and temporal properties that constraint an individual's ability / capacity / preference to access specific destinations (Witten, Exeter et al. 2003). Accessibility can be defined in terms of mobility, which includes a number of spatial and associated non-spatial attributes and their temporal constraints, on individuals or groups.

Accessibility can be measured by (Euclidean, Manhattan or network) distance, by travel (driving, public transport or walking) time or travel cost. Accessibility can be described as travel impedance (travel distance or travel time) between patient location and health care service points (Guagliardo 2004). Guagliardo (2004) argues that accessibility and availability are not similar terms and that accessibility may depend on availability of the services. In urban areas, where multiple service locations are commonly available, accessibility and availability should be considered simultaneously (Guagliardo, 2004). With regards to health care service utilization, accessibility is generally influenced by the spatial structures of health care service supply and demand, neither of which is distributed uniformly in space (Wang 2011). Table 2-1 shows some key areas of accessibility research, and key issues and measures of accessibility.

Table 2-1 Areas of accessibility research and issues and measures of accessibility

Area	Issue	Measures	Reference
Urban Planning	Residential development and accessibility to commercial, industrial, and residential locations	Gravity	Hansen (1959)
	Physical Planning	Modified Gravity	Geertman and Van Eck (1995)
Geography and health	Distribution and proximity impact on infant mortality.	Ratio	McLafferty (1982)
	Geographic accessibility to health care facilities in the rural area	Gravity	Thouez, Bodson et al. (1988)
Public policy	Health care deprivation	Gravity	Knox (1979)
	Residential mobility and location disadvantage	multi-dimensional	Maher (1994)
Public health	Health care in urban diabetic population	Travel time and distance	Liu (2008)
	Accessibility to public hospital	Travel time and cost (cost path analysis)	Brabyn and Skelly (2002)

2.4 Spatial accessibility

In a general sense, the term ‘access’ refers to an entrance into, the right of entry to, or the use of facilities, and the term ‘spatial accessibility’ refers to the physical accessibility one possesses to a preferred location, or the ease at which individuals in one location can reach another location (Pirie, 1980; Kwan and Weber, 2003). Spatial accessibility refers to the relationship between the locations of the supply of and the locations of demand for specific services, taking into account existing transportation infrastructure and travel impedance. In the literature, spatial accessibility (Freeman, 1986; Oppong and Hodgson 1994; Hewko, 2001; Guagliardo, 2004) and geographical accessibility (McLafferty, 1982; Pooler, 1987; Brabyn and Skelly, 2002; Apparicio et al., 2008) are often used in an interchangeable manner, in the sense that both concepts are location-based and spatially constrained, as Khan (1992) has noted that spatial accessibility is specifically conditioned by the spatial or distance variable (as a barrier or a facilitator of access) and the pattern generated has the most direct geographic manifestation. Some scholars declare that they used the term ‘spatial accessibility’ because they want to gain the favour and supported by the literature published in health care geography category (Khan and Bhardwaj 1994; Luo and Wang 2003; Luo, Wang et al. 2004 and Guagliardo, 2004). The spatial accessibility has been studied and developed mainly in Geography, Mathematics and Social science but not limited to physics, planning, public health, transportation, civil engineering etc (Figure 2-2). Spatial accessibility is a critical consideration in the provision of both public and private services (Murray 2003).

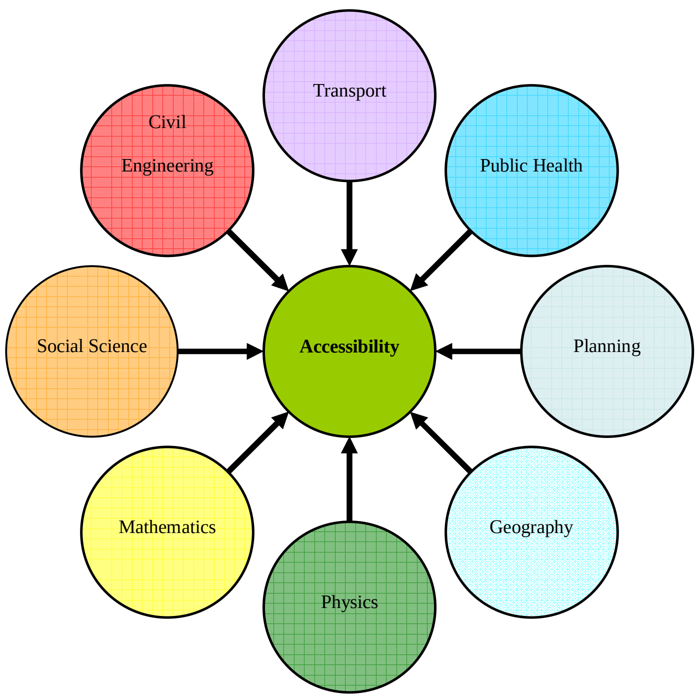


Figure 2-2 Study and development of the measures of spatial accessibility

Stewart (1942) discussed population-over distance relationship or population potential as a generalized notion of accessibility. According to the concept of population potential, Hansen (1959) conducted an empirical examination of the residential development patterns. Many other empirical studies have since been conducted and new concepts have been developed. The development of computer, mathematical and spatial statistical approaches and Geographic Information System (GIS) added new dimension in the development and application of accessibility measures in many different disciplines. Figure 2-3 shows the chronological development in the research of spatial accessibility.

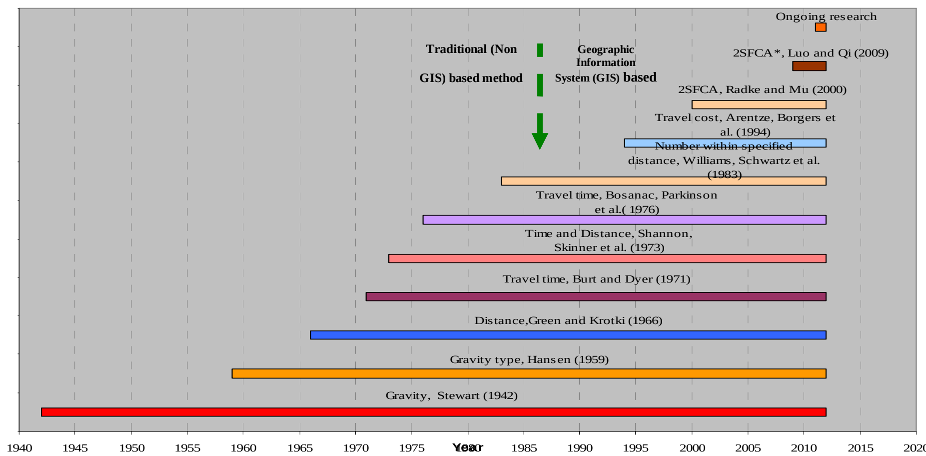


Figure 2-3 Chronological development in the research of spatial accessibility

In the literature, the terms ‘spatial accessibility’ and ‘spatial patterns of accessibility’ are sometimes used with no discrimination (Ikporukpo 1987; Bailey and Phillips 1990; Hays et al. 1990), but majority of the researchers taken the term ‘spatial accessibility’ to mean physically be able to reach from a potential location of the health care user’s to a health care facilities location via a transportation network, and the term ‘spatial patterns of accessibility’ to mean the spatial distribution of certain spatial accessibility measures .

2.5 Indicators / measures of spatial accessibility

Walizer and Wienier (1978) define indicator as ‘a class, set or group of potentially observable phenomena that represents a conceptual definition’. Indicators and measures of accessibility are important for any assessment of health care provision. There have been several attempts to develop indicators to measure and evaluate accessibility to health care services. In many situations, information used in indicator of accessibility to health care services overlaps with information used in other social, economic and planning indicators. Indicators consist of information which can be used to construct an index. For example, the Index of Multiple Deprivation 2000, commonly known as IMD2000, was developed by the British government, based on six categories of deprivation or 'domains' (Index), to determine which small areas are having poor geographical access and hence are eligible for more funding (Niggebrugge et al., 2005). The domains of the index include resident income, employment, health and disability, education skills and training, housing, and geographical access to services (IMD, 2000). The geographical access in IMD2000 was measured as straight line distance between the location of the population and some selected services. IMD2000 was used to identify poor accessibility clusters and isolated areas where 29% (n=14.4million) of the population of England were located (DETR, 2000).

Indicators of accessibility can be opportunity based (Wachs and Kumagai, 1973). Opportunities to access to a health care service can be specified in terms of a fixed threshold of travel distance or travel time (Vickerman, 1974; Ben-Akiva and Lerman, 1979). Here travel time includes notions of friction, barriers, connectivity and critical distance (Crews-Meyer, 2000). Euclidean distance (Noor et al, 2006; Crawford, 2006; Pang and Lee 2008; Liu, 2008; Apparicio et al, 2008) and network distance (Apparicio et al, 2003; Sharkey and Horel 2008) are often used to measure the distances between the health care service providers and users. Distance is related to access and utilization. The farther the travelling distance to a service facility, the less likely an individual will use the service facility (Sherman et al, 2005). Distance can be measured from different locations of importance to individuals, for example, from the home or workplace. Some studies have found a greater propensity for individuals to utilize health services near a place of employment rather than their residence (Gesler and Meade 1988; Fortney, Rost et al. 2000). Niggebrugge et al (2005) mentioned two additional indicators of accessibility as calculated using GIS: road length in measured in kilometres per thousand populations, and the presence of a major road in each local community, both were found to have enhanced the power of the IMD2000 index.

Some researchers have argued that the effect of distance on the use of health services is affected by the time and cost of travel, compounded by topography and poor road conditions (Vissandjee Barlow et al., 1997; Toan et al., 2002), and by a shortage of public transport (Mwaniki Kabiru et al., 2002; Krasovec, 2004). Poor road conditions were associated with longer travel times to reach health care facilities, whereas better road conditions were associated with regular visits to a physician (Ramsbottom-Lucier et al, 1996). Therefore, good road conditions can be one accessibility indicator because it assists human mobility within an area. If there is an improvement of the transportation network, then it might be anticipated that there will be a change in the level of access to health care facilities (Wachs and Kumagai 1973). Having a vehicle and a good road network could be an advantage over the use of a public transportation system. People with a car can travel to the nearest health care facilities with a reduced travel time compare to those who do not have a car and have to rely on public transport.

Increased travel distance will increase travel time which directly or indirectly impacts on travel cost as the user takes the effort to organize their time to visit a health care service. Penchansky and Thomas (1981) describe this concept as affordability. Bice, Eichhorn et al. (1972) argues that affordable or subsidized health services provided through Medicare have played a major role in increasing access to health care services in Australian (and Victoria). Talen (2001) examined this concept of health care facilities to education services. She found that the distribution of travel cost between resident locations (blocks) and schools is equitable on the basis of the density of resident populations and the socioeconomic status (SES) of resident populations. Spatial inequities in access to school were substantial and varied by county and school zone. She argues that these issues are potentially relevant when considering health care service access (Talen, 2001). Thus, the location where an individual lives is a sensible health care service accessibility indicator which may be influenced by whether the area is urban, rural or urban fringe area.

Indicators like the ratios of number of health care providers or facilities to population are often used to evaluate the degree of access to care in a designated catchment area. For example, facility-user ratios (the number of users per facility), doctor-patient ratios, hospital bed-population ratios, nurse-patient ratios, among others, can be used (Cervigni et al, 2008). Key considerations and measures of accessibility are summarized in Table 2-2 and the most commonly used measure of accessibility are listed in Table 2-3, which include: (1) measures based on the gravity potential model, (2) measures based on travel impedance (distance, travel time and travel cost), and (3) measures based on number of facilities within specified travel impedance.

Among other accessibility measures utility based measure is complex because in this model individuals' utility using behaviour e.g. travel behaviour, their decision-making preferences e.g. individuals time or ability and satisfaction are used. Space-time accessibility measures is utility based accessibility measure and it have received much attention in recent years due to their sensitivity to differences in individual ability to participate in activities in space and time (Miller 1991, Kwan 1998; Weber and Kwan 2003),. Space-time accessibility measures are based on the construct of the space-time prism proposed by Hägerstrand (1970) which able be visualized individuals activities and travel in 3D space-time.

On the other hand, the two-step floating catchment area (2SFCA) method is inspired by the spatial decomposition idea or special type of gravity model was first proposed by Radke and Mu (2000) to assess social programs. Luo and Qi (2009) improved the model for measuring spatial accessibility addressing the problem of uniform access within the catchment by applying weights to different travel time zones to account for distance decay. This model does not have a distance friction function it relies on a predefined travel threshold (Wang, 2011) even though it becomes widely accepted.

Table 2-2 Key consideration and measures of accessibility

Dimension	Key Consideration	Measures	Reference
Spatial	Number of facilities within specified area/distance	Count	Apparicio (2008)
	Network distance to specified service	Length	Ingram (1971), Apparicio, Cloutier et al. (2007)
	Travel cost and travel time	Cost and time	Talen (2001), Higgs (2004)
	Average distance to specific number of facilities	Length	Talen (1998)
Temporal	Available consultation hour	Time	Campbell et al (2005)
Theme	Demography cost of services, health insurance.	Statistics	Field and Briggs (2001)

Table 2-3 Commonly used measures of accessibility

Measures of accessibility	Reference
Gravity potential Model	Stewart (1942), Hansen (1959)
Distance between user and health care service facilities	Green and Krotki (1966)
Travel time between user and health care service facilities	Bosanac and Parkinson et al (1976)
Travel cost between each user and all service facilities	Airey (1992)
Number of facilities within specified distance.	Apparicio et al (2008)

2.5.1 Measures based on the gravity potential model

Gravity potential model is the most commonly used measure of spatial accessibility found in the literature (Pacione, 1989; Talen, 1998). The model is based on Newtonian physics, where facilities are weighted by their capacity and adjusted for the friction of distance (Cho, 2003). The general formula for gravity-based spatial accessibility is (Guagliardo 2004):

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

Where A_i is spatial accessibility from population point *i* which may be a personal residence or the centre of an area of interest (e.g. MB centroid); S_j is service capacity at provider location *j*, which reflected the number of providers at the location and their combined capacity for health care provision; d_{ij} is the travel impedance, e.g. shortest network distance between points *i* and *j*; and β is a gravity decay coefficient, sometimes referred to as the travel friction coefficient, representing the change in difficulty of travel as travel distance or time change.

Initially, the gravity model was only used to model supply, and there was no adjustment for demand. Joseph and Bantock (1982) proposed a new equation to account for spatially varying population demand:

$$A_i = \sum_j \frac{S_j}{d_{ij}^{\beta} V_j} \text{, and } V_j = \sum_k \frac{p_k}{d_{kj}^{\beta}}$$

Where V_j is the population demand on service provision at location *j*, obtained by summing the gravity-discounted influence of all population points within a reasonable distance, and P_k is population size at point *k*, (e.g the centroid of a MB) (Joseph and Bantock, 1982).

Hansen (1959) has shown that values of A_i may range from 0.5 to 3.0. He argues that the variation in the exponent for different trip purposes seems reasonable when only those examinations conducted within urban areas are considered. He points out that studies indicate decreases in the exponent as trips become more important and suggests different exponent value for school trips (2.0+), shopping trips (2.0), social trips (1.1), and work trips (0.9). A decrease in the exponent means that distance becomes a less restrictive factor for the related tips, i.e. people are willing to travel further than they are for other trip purposes (Hansen, 1959).

Talen and Anselin (1998) demonstrate that accessibility improves if the number of providers increases, if the capacity at any provider location increases, if the distance to the provider decreases, or if the travel friction decreases. Talen and Anselin (1998) also point out two problems in computing spatial accessibility over a field of population point for studying geographic variation: first, the value of the decay coefficient is often unknown (Talen and Anselin, 1998), particularly for health care facilities; and second, the A_i scale cannot be easily estimated e.g., the provider - population ratio (Guagliardo et al., 2004).

2.5.2 Measures based on travel impedance

The two most common types of distance measure used for determining spatial accessibility in the literature are the Euclidean distance (more often known as straight line distance) and the Manhattan distance (distance along two sides of a right-angled triangle, the base of which is the Euclidian distance). Ingram (1971) suggests that the Manhattan network distance measure is more appropriate than Euclidean distance in measuring gridded road network in urban areas. But Apparicio et al (2008) argues that the shortest network travel time is more accurate than any other distance measures.

Spatial accessibility to service facilities from population points have been determined using travel time (Burt and Dyer 1971), where travel time is often calculated using the existing road network, the distance is converted to travel time by using a suitable conversion algorithm and the travel time is also dependent on the mode of transportation used, e.g. travel by car or public transport (Figure 2-4).

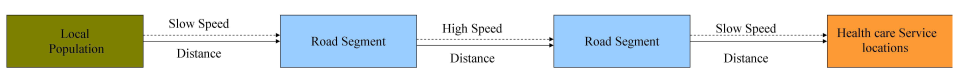


Figure 2-4 Varying travel impedances involved in driving to a health care service location via a road network (adapted from Burt and Dyer, 1971)

From a user's perspective the journey can be more complex on public transport, and factors such as walking between transport stops or stations, waiting for the next available transport and other scenarios need to be considered (Figure 2-5).

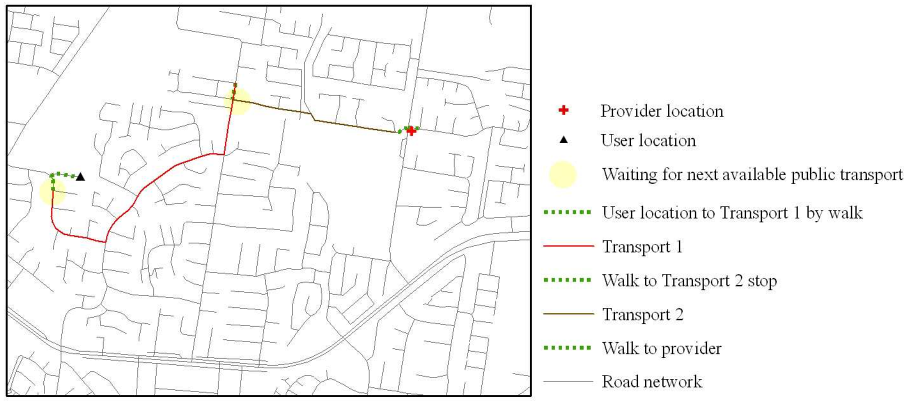


Figure 2-5 Varying travel impedances involved in travelling from user location to provider location, with walking components

Travel cost is an alternative method for measuring spatial accessibility (Pearce Witten et al 2006). Like the shortest network distance by time, travel cost also uses the road network system and is measured by using the distance travelled and a suitable conversion algorithm. Calculating the travel cost for travel between the user's location and health service provider is therefore relatively simple.

2.5.3 Measures based on number of facilities within specified areas

The number of facilities within a specified travel impedance (e.g. travel distance, travel time or travel cost) is a commonly used method to measure spatial accessibility. Distance can be measured either from the supply perspective, e.g. catchment area for a specific health care service, or from the individual users perspective, e.g. distance to the closest health care service facility (Fryer et al., 1999, Fortney, Rost et al, 2000) or both (Parker and Campbell, 1998). For example, Apparicio et al (2008) have used the following measures of spatial accessibility: the number of facilities within a specified distance, average distance to 3 closest services; average distance to 5 closest services, and average distance to all services.

2.6 Indicators / measures of spatial patterns and spatial associations

Spatial patterns can be defined as the spatial arrangement of objects on a designated surface by their spatial locations. There are a number of spatial statistical approaches in the literature to describe spatial patterns. Spatial statistics have been used in a range of accessibility studies (e.g. Talen and Anselin 1998; Algert, Agrawal et al 2006; Apparicio 2007; Sharkey Horel et al 2009; Jiang et al 2011), including indicators of both global and local patterns of spatial associations, and more and more emphasis on local patterns of spatial association.

There are only a few examples in accessibility studies where spatial statistical measures especially Moran's I were used. It has also appeared that local spatial pattern analysis is more popular than global spatial pattern analysis. Apparicio et al (2007) used spatial statistical analysis to identify spatial clusters. Jiang et al (2011) used global and local Morna’s I statistics for exploratory data analysis purposes, visualize and understanding spatial distribution and spatial association between variables. Global spatial pattern analysis has been used in this study to understand the global pattern of the data and local spatial pattern analysis (local Moran and hot spot analysis using Getis-Ord Gi*) has been used to identify cluster of high or low accessibility areas have been given to indicators of local patterns of spatial association.

2.6.1 Measures of global spatial patterns

Tobler’s first law of geography states that ‘everything is related to everything else, but closer things are more related than distant things’ (Tobler, 1970), which has been commonly considered as the foundation of spatial autocorrelation and other spatial-statistics. Informed by the first law of geography global spatial statistics has been developed for analyzing the overall spatial pattern or trend of the collected data.

Global statistics indicates correlation of a variable with itself through space (Chen, J., C. Yanan, et al. 2011). Two most commonly used global spatial statistics are: Morans I and Getis-Ord General G.

The global spatial statistic Moran's I (Moran, 1950) measures global spatial autocorrelation based on feature locations and associated attribute values (Moran, 1950). Moran's I measures both the proximity of locations and the similarity of the characteristics of these location. The proximity of locations is often specified in terms of various forms of inverse distance between points *i* and *j*, and the similarity of attribute values between two points can be calculated in terms of the difference between each attribute value and the mean of all attribute values in question.

Moran's global I statistic measure spatial autocorrelation without distinguishing between patterns dominated by concentrations of high or low values. The Getis-Ord General G statistic enables these cases to be distinguished.

The Getis-Ord General G statistic measures the degree of clustering for either high values or low values or concentration of high or low values for a given study area. This global spatial statistics are most effective when the spatial processes being measured are consistent across the study area. Results will then be a good representation or summary of the overall spatial pattern (Getis and Ord 1992). The Getis-Ord General G statistic tends to have a high value when the locations where high values are located near one another outweigh the locations where low values are located near one another (and vice versa), and thus helps to determine whether it is clusters of high values ("hot spots") or low values ("cold spots") that contribute most to an overall finding of positive spatial autocorrelation

The Getis-Ord General G statistic has been implemented as the high/low clustering tool in ArcGIS (ESRI, 2012a). Used as an inferential statistic the results of the analysis can be interpreted within the context of a null hypothesis. The null hypothesis for the general G statistic states "there is no spatial clustering of the values". When the absolute value of the z score is large and the p-value is very small, the null hypothesis can be rejected. If the null hypothesis is rejected, then the sign of the z score becomes important. Positive z score value means high values cluster together in the study area where negative z score value means low values cluster together (ESRI, 2012a)

2.6.2 Measures of local spatial patterns

In many spatial analyses it is necessary to know the degree of spatial association between variables. More recently a number of additional model of spatial statistics, known as local spatial statistics have been developed to measure association between a single x_i and its neighbours within a specified distance (Getis and Ord 1996). There are many local spatial statistics available for measuring spatial association and identifying spatial clusters (e.g. hot spots and cold spots), such as Getis-Ord Gi* statistic, Local Moran’s I, and Local Indicator of Spatial Association (LISA).

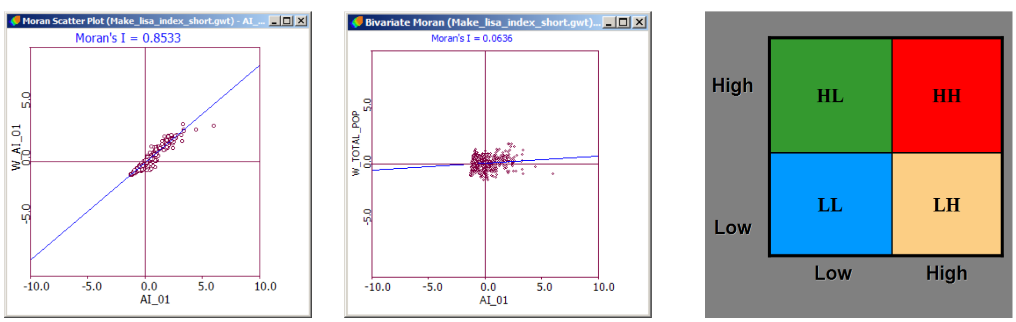
The Getis-Ord Gi* statistic is a local spatial statistics (Getis and Ord 1992) commonly used in hot spot analysis for assessing local spatial patterns and trends. This statistic is popular in crime analysis, epidemiology, voting patterns, economic geography and demographics. In ArcGIS, the Getis-Ord Gi* statistic is implemented as the hot spot analysis tool. The Gi* statistic indicates whether features with high values or features with low values tend to cluster in a study area: if a feature's value is high, and the values for all of its neighbouring features are also high, it is a part of a hot spot; if a feature's value is low, and the values for all of its neighbouring features are also low, it is a part of a cold spot. The Gi* statistic returned for each feature in the dataset a z-score: for statistically significant positive z-scores, the larger the z-score, the more intense the clustering of high values (hot spot); for statistically significant negative z-scores, the smaller the z-score, the more intense the clustering of low values (cold spot).

Local Moran's I, commonly known as Anselin Local Moran's I, is often used to identify statistically significant hot spots, cold spots, and spatial outliers (ESRI, 2012b). A positive local Moran's I value indicates that the feature has neighbouring features with similarly high or low attributes values and hence this feature is part of a spatial cluster. A negative local Moran's I value indicates that a feature has neighbouring features with dissimilar values and therefore this feature is a spatial outlier. In either instance, the p-value for the feature must be small enough for the cluster or outlier to be considered statistically significant. The output field, cluster/outlier type (COType), distinguishes between a statistically significant (0.05 level) cluster of high values (HH), cluster of low values (LL), outlier in which a high value is surrounded primarily by low values (HL), and outlier in which a low value is surrounded primarily by high values (LH) (ESRI, 2012a).

Local indicator of spatial association (LISA) is any statistic that satisfies two requirements: (a) for each observation it gives and indicates the extent of significant spatial clustering of similar values around that observation; (b) its sum for all observation is proportional to a global indicator of spatial association (Anselin 1995). A randomization approach is often used to generate a spatially random reference distribution to assess statistical significance. LISA maps are particularly useful to assess the hypothesis of spatial randomness and to identify local hot spots. LISA can be done with single variable (univariate LISA) or with multiple variables (bivariate

LISA). Univariate LISA maps may mask multivariate associations, variability related to scale mismatch, and other spatial heterogeneity (Geoda Center, 2012).

Values of Local Moran's I can be represented in a scatterplot, with the vertical axis represents the spatial lag of the variable and on the horizontal axis the original variable (Anselin, 1992). Figure 2-6A shows 4 quadrants for univariate Moran's I scatterplot with variable in *x* and *y* axis, and Figure 2-6B shows a multivariate Moran's I scatterplot with variables in *x* and *y* axis. In the scatterplots, as shown in Figure 2-6C, high-values surrounded by high values is represented as HH points (red) in the upper right quadrant, low value surrounded by low values is represented as LL points (blue) in the lower left quadrant, low value surrounded by high value is represented as LH points (light orange) in the lower right quadrant, and high values surrounded by low is represented as HL points (green) in the upper left quadrant.



A. Univariate Morans I scatter plot

B. Multivariate Morans I scatter plot

C. Interpretation of Morns I correlation quadrants

Figure 2-6 Interpretation of the data points in the 4 quadrants of a univariate and multivariate Morans I scatterplots

Gi* and LISA statistics are two different measures of spatial association. Positive values in Gi* statistic indicates a spatial clustering of high values whereas negative values indicates a spatial clustering of low values. In contrast, for the LISA, a positive value indicates spatial clustering of similar values (either high or low), and negative values a clustering of dissimilar values e.g. high values surrounded by neighbours with low value and vice versa (Anselin, 1995). This study used only univariate LISA analysis techniques.

2.7 Conclusion

Based on literature review, this chapter clarifies the terms access, accessibility and spatial accessibility and draw a distinction between those terms. This chapter also highlights the development of the accessibility measures in different disciplines over time. It is clear that road network based shortest travel distance and shortest travel time are preferred measures of spatial accessibility. Travel distance and travel time based service catchment area analysis are often used to the estimation of population within a service catchment area. Shortest travel distance based gravity index have been used to measure spatial accessibility to health care facilities locations from their potential users location. Exploratory spatial data analysis, spatial statistical approaches, and global and local spatial statistical measures have been used to identify trends and locations of spatial clustering.

Chapter 3 Research Methodology

3.1 Introduction

This chapter describes the GIS-based research methodology developed for characterizing spatial variation in access to health care facilities in terms of the spatial distributions of potential users, health care facilities, and transportation infrastructure, and for identifying local communities where spatial accessibility to health care facilities is relatively poor.

The Chapter begins with some clarification of key concepts and definition of relevant terms used in this thesis, and then followed by sections on the following issues: considerations for selecting the case study area; data requirements of the study; data collection and preparation; the development and application of geoprocessing and spatial analytical procedures; and the steps involved in the generation, evaluation and refinement of the outputs (e.g. maps, tables, charts).

3.2 Conceptualizing spatial accessibility

Accessibility has three inter-related dimensions: spatial, temporal and thematic (Figure 3-1). The interactions among these three dimensions have significant influences on health care facility accessibility. Accessibility can be discussed either individually or in various combinations of these three dimensions, from either the service user's perspective or the service provider's perspective.

Due to time constrains and the complexity of including the temporal dimension (e.g. accessibility in 24 hour time window), this study concentrated on the spatial dimension (e.g. location of the health care facilities) and the thematic dimension (e.g. socio-economic and demographic characteristics of the potential users), as indicated by the shaded area in Figure 3-1. Accessibility can be conceptualized as an interaction of three interrelated dimensions: space; time and theme (attribute e.g. characteristics of population or opening hour of a GP/Surgeon clinic). Thematic accessibility can be conceptualized as an interaction of non-spatial factors of two different entities; for example an interaction between the characteristics of population e.g. low income population and characteristics of health care facilities e.g. cost for service can be considered this way.

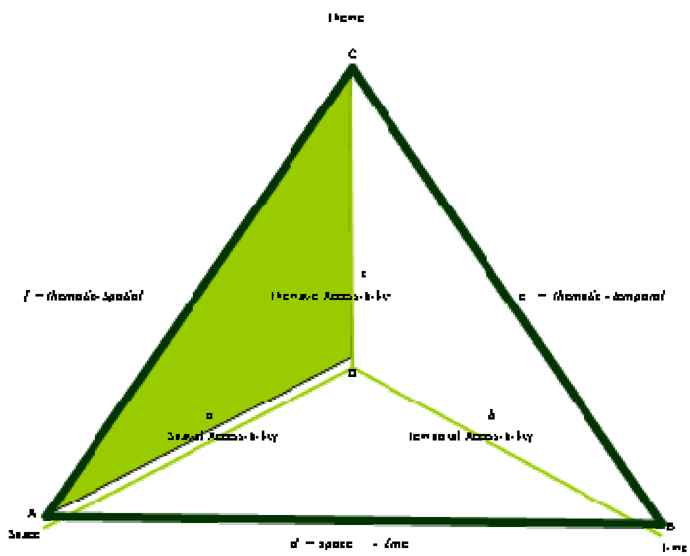


Figure 3-1 Accessibility in terms of the interaction of space, time and theme (based on personal discussion with Dr Gang-Jun Liu[1])

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[1] This figure has been developed during the confirmation of candidature with the help of Dr. Gang-Jun Liu.

Spatial accessibility is conceptualized in this study as the easiness for reaching a destination location (e.g. location of health care facilities) from a Mesh Block (MB) centroid by a member of the local community who is driving a car, and measured as the travel distance or travel time to the nearest health care facility via a transportation network.

3.3 Selecting a study area

To uncover spatial variations in accessibility to health care facilities from a dispersed population using a variety of transportation modes, a case study area with a combination of urban and rural qualities is regarded as desirable. So the decision has taken to focus on the Shire of Cardinia, which is located on the outer fringe of metropolitan Melbourne, 65 km south-east of Melbourne GPO (See Figure 3-2). Further details about the case study area will be presented in chapter 4.

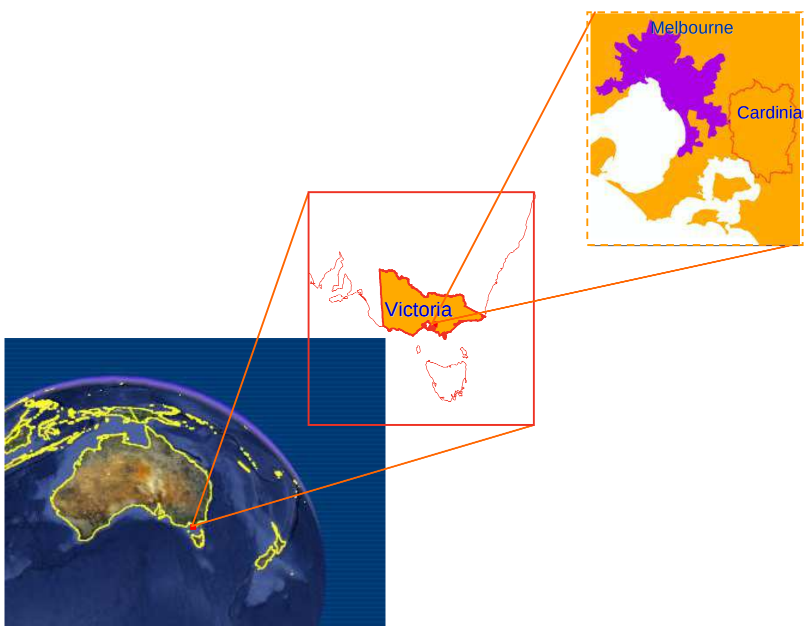

Figure 3-2 Select a case study area

3.4 Specifying the research outputs

The study aims to develop a GIS based method for the investigation of spatial accessibility to health care facilities at fine spatial resolution, and for mapping the spatial variations of population, health care facilities and transportation system, uncovering spatial variation in spatial accessibility, and identifying disadvantaged locations / local communities.

To map spatial variations in population, health care facilities and transportation system within the study area, this study used fine spatial resolution data set. The Spatial distribution of population at MB level is mapped to show how the residential population varies spatially. Using residential address points and a method described by Millet et al (2010), a residential address cluster has also been developed to validate population distribution. To map spatial variations in the distribution of health care facilities, address locations of selected health care facilities has been collected and geocoded and the overall health care facilities and population ratio and the number of facilities per locality are derived. The spatial configuration of the transportation system in the study area is mapped in terms of the spatial layout of the road network and the public transportation services (e.g. bus and train). As there is no data for the travel behavior of the resident population, the method of travel used to reach work, car ownership and proportion of population work within the study area has been used as a proxy.

It is assumed that there exists a spatial variation in the distribution of the population, health care facilities and transportation infrastructure, which may have some influence on spatial accessibility to health care facilities. So it is important to investigate spatial variations in spatial accessibility to health care facilities in a finer spatial resolution.

Exploratory data analysis with Geoda and thematic mapping with ArcGIS has been used to visualize the spatial variations in population, health care facilities, transportation system, and spatial accessibility. Exploratory data analysis in Geoda provides useful rocedures for identifying spatial variations in the data set. Geoda offers box plot and histograms using the attributes of the data also can generate four different types of maps e.g. Quantile maps, Percentile maps, Box plot maps, Standard Deviation map. Visualization and measurement of spatial variations in the distribution of the population, health care facilities and transpiration, as well as accessibility index helps to describe and analyze spatial patterns and spatial associations among the demand for health care services, provision of health care services and accessibility to health care facilities within the study area.

Statistical analysis of spatial patterns helps the identification of locations where accessibility to health care facilities is relatively poor. Approaches for investigating spatial patterns and measuring for identifying disadvantaged locations will be presented in section 3.7.4.

3.5 Specifying the input data requirements

To investigate spatial accessibility to health care facilities, three main types of data are required: the location of the population and their main characteristics, the location of the health care facilities, and the spatial layout of the transportation system (e.g. road network).

Locations and characteristics of the resident population are needed to characterize the demand for health care services. Census data contains detailed and vital characteristics of the local communities (e.g. age and gender distributions, personal and household income levels, car ownership, employment, etc). For the 2006 census, community profile data are aggregated and made available only at the Census Collection District (CD) level. The study developed a method to disaggregate the census data into a finer spatial resolution, i.e. the Mesh Block (MB) level. MBs are the smallest geographic regions in Australian Statistical Geography Standard (ASGS) (Australian Bureau of Statistics, 1995). Due to limited availability of data on users' travel behaviour and users' preference to health care facilities in terms of professionals, costs, gender or culture, this study assumed that the residents will travel to their respective nearest health care facilities, according to the first law of geography, and assumes that all facilities are equal in terms of user's preference.

Locations for the selected types of primary health care facilities, i.e. pharmacy, GP/Surgeons clinic and dental clinic, within a 1.5 km buffer of the study area, are collected to account for possible edge effects[1]. This may be adequate for

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[1] there are not many health service facilities beyond the Shire boundary – e.g. the southern part in the study area has a boundary with the cost line, in the north there is a massive water body (Cardinia water Reserve) and in the North-East large natural reserve (Bunyip State Park). Precisely there are no available services within those areas.

On the other hand, there are also a few data limitations in this study – e.g. the study do not know the residents health seeking behaviour (e.g. the residents preferred health care facilities or how far they willing to travel to etc or if there is a health care facilities preference is it for good service, close proximity or low cost).

Without knowing the residents health seeking behaviours, it is difficult to distinguish who is using what services and therefore difficult to specify a pertinent buffer distance.

A 1.5 km buffer is set to include all health care facilities that are located beyond the Shire's boundary but within the maximum distance an ordinary person is willing to walk to consume these services.

walking based travel but may be inadequate when driving is the main mode of transportation. Census data analysis has revealed that more that 55% of working population travel outside of the study area for their work. They may find more suitable health care facilities and professionals next to their workplace or in between their work and home, however this is not known.

Data on road transportation infrastructure (road network) and associated speed limits was collected to measure travel distance and travel time between health care facilities and the local communities. The public transportation network (e.g. bus stops and bus routes, and train stations and railway lines) were also collected to better understand the patial layout of the transportation network across the study area. In the study area, the proportion of the population using public transportation, walking, bicycling is significantly low. Therefore, car based transportation was chosen in this study as the only mode of transportation between the location of the population and the health care facilities. Train and bus based public transportation infrastructure have been used to identify the overall condition of transportation systems, but they were neither integrated into the travel distance and travel time measurement nor included in the calculation of accessibility index.

In addition, address points were required to geo-code the location of all health care facilities, and other spatial data sets such as the Cardinia Shire boundary, locality boundaries were also required to provide a realistic geographical context or spatial framework of the study area.

3.6 Data collection and preparation

This section describes the data sources (see Table 3-1) and procedures for data collection and preparation.

Table 3-1 Required input data and data sources

Data source	Data type	Description	Data format
ABS	Spatial	Mesh Block boundary	Polygon
		Census Collection District Boundary	Polygon
	Attribute	Census Collection District level population census of 2006	Excel Table
VicMap	Spatial	Address points	Point
		Admin boundaries (Shire and locality boundary)	Polygon
		Road network	Line
		Rail network, train stations	Line, Point
Metlink	Spatial	Bus routes, bus stops	Line, Point
	Attribute	Time tables	PDF
DHS	Address and attribute	Health care services locations and attribute	Excel Table
Yellow Pages	Address and attribute	Health care services locations and attribute	CSV

Census data and associated spatial boundaries were collected from the Australian Bureau of Statistics (ABS) website (www.abs.gov.au). Detailed 2006 census data are available only at the CD level in zipped Excel table format. There are 74 CDs in the study area. Those zipped files were downloaded and then extracted using WinZip. Figure 3-3 illustrates the census data preparation procedure. The main attribute associated with health care facilities are the location address of the facilities, service type, name of the professionals and phone number. There are few facilities where fee types (e.g. bulk billed or not) and opening hour has been disclosed.

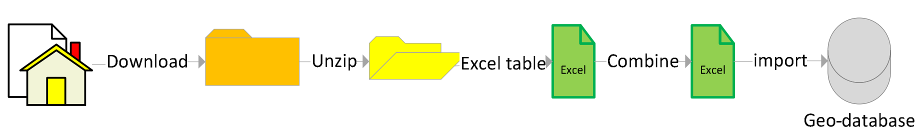


Figure 3-3 Census data preparation procedure

The addresses of the health care facilities have been collected from two different sources: (a) Department of Human Services (DHS) website (www.dhs.vic.gov.au), and (b) Yellow Pages Australia website (www.yellowpages.com.au) by health care types. Those two datasets were then merged together; .duplicate addresses for each health care type were identified and deleted to get a single unique address for each health care facility. Then this table of addresses was geocoded using ArcGIS, un-matched addresses were identified in Google Earth and summarized in a kml file, which was exported to shape files and then merged with those already geocoded addresses. A total of 184 locations of health care facilities were initially identified but later on 15 of them had to be excluded, because 5 health care facility locations were unmatched by any means during the geo-coding process and 10 health care service locations were outside of the 1.5km buffer zone of the study area. Finally, the geocoded addresses of Pharmacies, GP/Surgeons clinics and dental clinics were imported into a geodatabase for supporting subsequent visualization and analysis. Figure 3-4 illustrates the health care facilities data collection and preparation procedure.

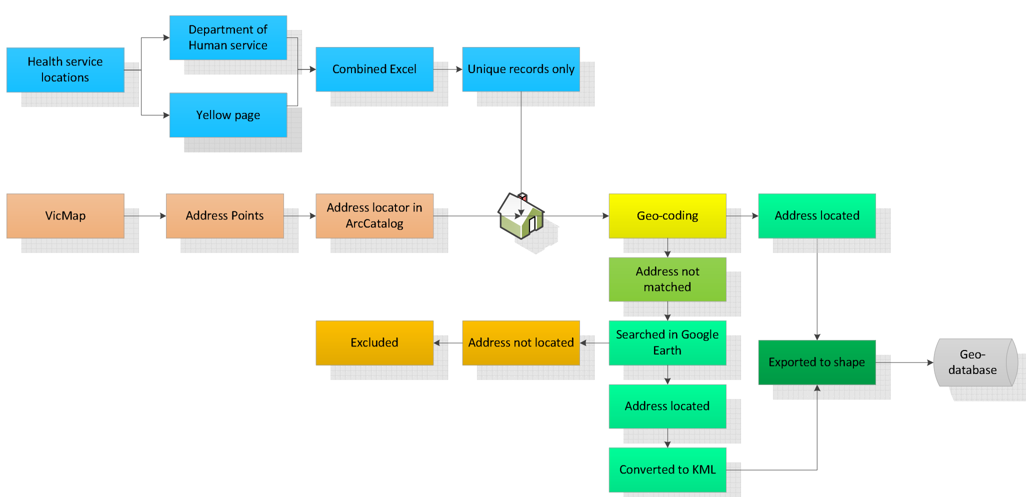


Figure 3-4 Health care facilities data collection and preparation procedure

Information about the transportation infrastructure network was collected from the VicMap Data Service. All the roads within 10 kilometres of the study area were included to get a comprehensive overview. Based on Vicroads road speed limits, travel time was calculated based on the length of the road segment. A Network dataset was then developed to measure the travel time and travel distance between the health care facilities and the location of the local residents (e.g. MB centroid). Afterwards, shortest travel distance and shortest travel time has been measured, and the shortest travel distance service area and shortest travel time service areas were derived. Figure 3-5 illustrates procedures for the preparation of transportation network dataset and for conducting network analysis. Data on the public transportation network (e.g. train stop and train lines) have also been collected from the VicMap Data Service. Bus routes were digitized using Metlink's bus route network map. Both train and bus services were used in this study to gain a better understanding of the available transportation system in the study area. All three types of transportation infrastructure were then imported into a geodatabase.

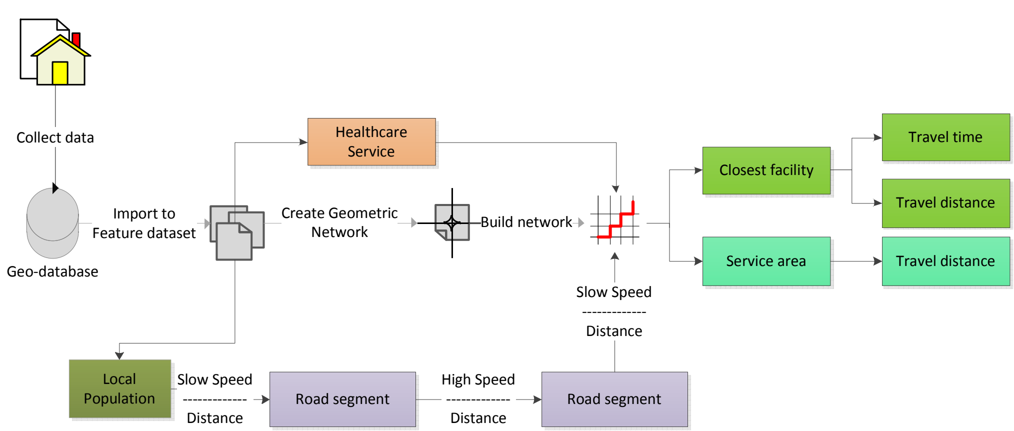


Figure 3-5 Preparation of transportation network dataset

In this study, the shortest network distance and shortest travel time has been chosen to measure the proximity between the health care facilities and the user of those facilities (Figure 3-6) because shortest network distance and shortest travel time both provides most realistic distance measures. A simplified network analysis setting have been established in the ArcGIS Network Analyst tools to measure the travel distance and travel time between the health care facilities and the population centres (MB centroids). Only four different road speed limits (40, 50, 80-90, 100 km/h) were assigned based on the Vicroad's road speed limits without considering road condition and topography. Network stetting allows U-turn at intersections and stop at any point. Traffic lights are not considered by assuming that health care service users from location *i* are able to travel to a health care facility at location *j* without any disruption. In reality, such assumptions may not be hold true and hence may increase the travel time of the users.

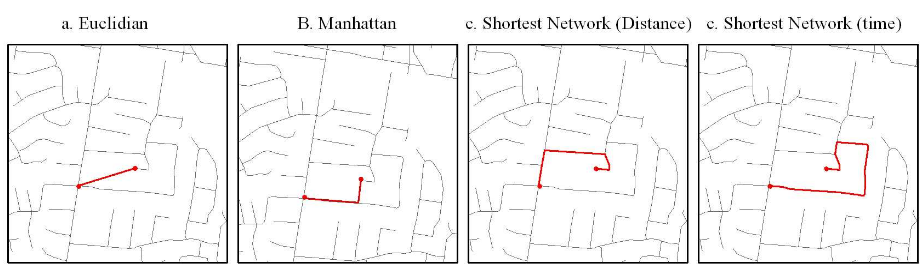


Figure 3-6 Travel impedance measures between health care facilities and their users

Other data sets used in this study include: CD and MB boundaries, collected from the ABS website; address points, localities and local government area boundaries, collected from the VicMap Data Service. All those data sets were imported into a geodatabase for supporting subsequent mapping and analytical efforts.

3.7 Geoprocessing and analytical procedures

After all the datasets required for this study have been collected, prepared and organized into a geodatabase, a number of geoprocessing and analytical procedures have been developed to derive the outputs specified in section 3.5 that are required to answer research question in section 1.2.

To reveal useful spatial variations in accessibility to health care facilities, it is necessary to use spatially refined data as input. Census data collected from ABS at the CD level has been transferred to MB level using a simple area weighted areal interpolation method developed specifically for this study (see details in attached Ahmad et al 2009 article in Appendix A). To reveal spatial variation in accessibility to specific types of health care facility by a local resident, it is necessary to first map the spatial distributions of the population variables, of the health care facilities, and of the transportation system across the study area.

3.7.1 Mapping spatial distributions of population, health care facilities and transportation system

Local population have been characterized and mapped by using the following census variables: percentage of female, aged and dependent child, unemployed adult population, proportion of family / household has less than 2 cars, and dwelling has income less than 499$ per week. The reason those variables are chosen are: those are available in the census data and those are regarded as the most important components of the demographic and economic characteristic of the local residents in the literatures. The spatial distributions of those variables are visualized using thematic maps (e.g. count, proportion, percentage, density etc), these thematic maps are cross-checked with map of residential address cluster derived from the Vicmap address points using the clustering method developed by Lampin-Maillet, Jappiot et al. (2010).

Health care facilities have been investigated in terms of the spatial distribution of these facilities, the number of facilities by localities and the overall health care facility and population ratio. Characteristics of the health care professionals are highly desirable to the characterization of health care facilities accessibility. Important components of health care providers including working hours of the health care professionals within selected health care facilities, languages and gender of the health care professional was not identified and characterized. Due to limited access to these data, all these important features are assumed to be equal at each of those facilities.

The transportation infrastructure has been investigated in terms of its overall condition of the transportation system. Proportion of population that has less than 2 cars and proportion of population who travel to work using public transportation system has been used as a proxy to justify the need for the use of car based travel in this study.

3.7.2 Measuring spatial accessibility to health care facilities

ArcGIS Network Analyst has been used to build a road network dataset and measured the shortest network distance and shortest travel time from each MB centroid to its closest facilities. Link impedance has been measured in metres. All possible shortest routes to the nearest health care facilities, as well as, the accumulated total road length have been identified for all the MB centroids in the study area.

Similar to the measurement of travel distance, measurements of car based travel time along the road network between health care facilities locations and all MB

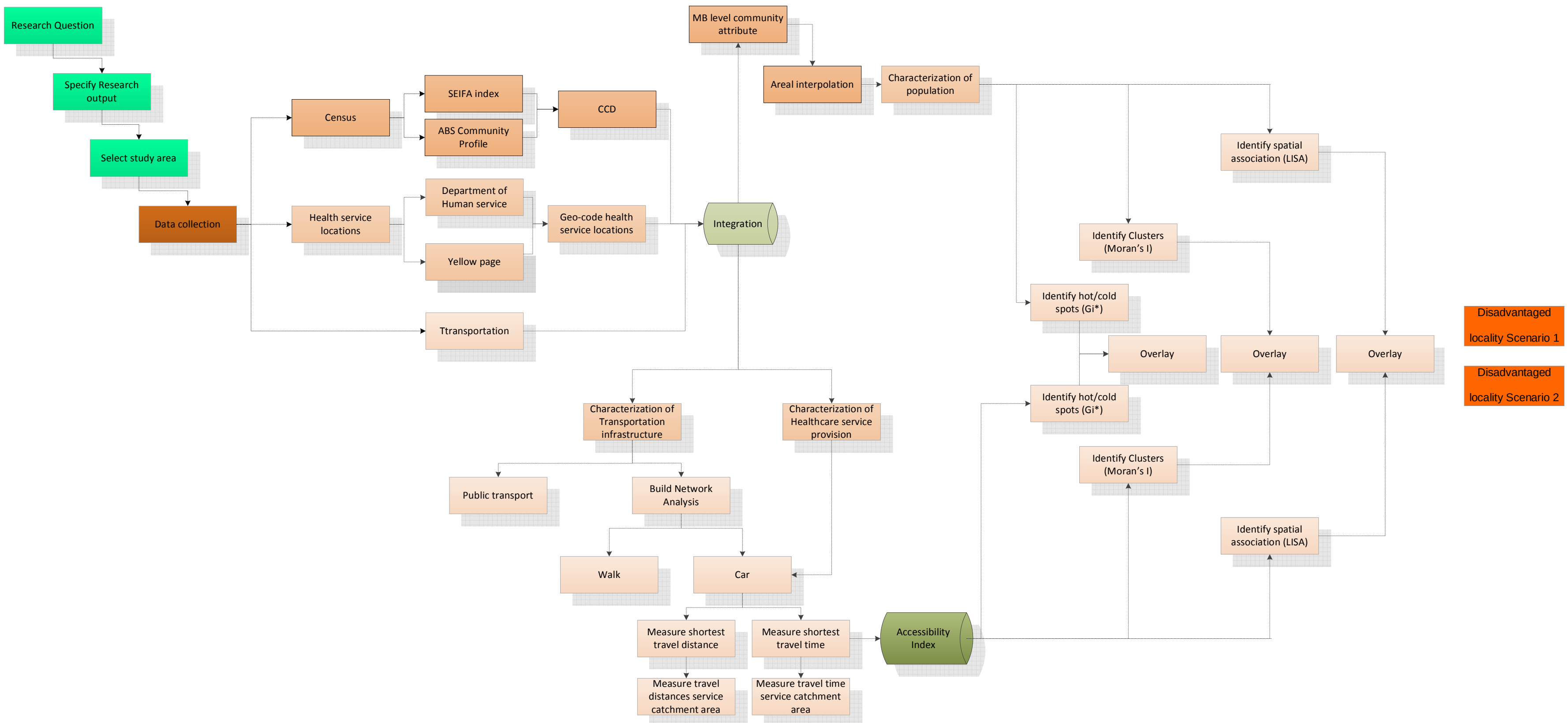


Figure 3-7 Overall research framework

centroids have been undertaken using road length and travel speed. Travel time has been derived using the following equation:

$$T_{ij} = \sum_{k=n}^{h} (\frac{l_k}{v_k})$$

Where T_{ij} is travel time between a MB centroid *i* and its closest health care facility location *j* specified by a road network distance of $\sum_{k=n}^{h} l_k$, where l_k is the length of the road segment *k* and v_k is the speed limits on road segment *k*.

The road network dataset created for measuring the travel distance was also used to measure car based service area. Travel impedance was measured in metres with break distance values set at 400m (metres), 800m, 1,200m, 5,000m, 10,000m, 15,000m, 20,000m, 25,000m, 30,000m, 35,000m, 40,000m, 45,000m and 99,999m. Among them, 400m, 800m and 1,200m are used to identify areas that are accessible by walking, and 99,999m was set as the maximum distance to avoid errors in the computation of service area. Likewise, in measuring the travel distance, U-turn is permitted at any road junctions, while direction is measured away from the health care facilities. Generalized polygons were created for each health care facility. Service areas based on car travel time measured with break time values of 5*m (minutes)*, 10*m*, 15*m*, 20*m*, 25*m*, 30*m*, 35*m*, 40*m*, 45*m*, 50*m*, 55*m*, 60*m* and 999*m* were also generated for each type of facility.

Using the travel distances to the nearest health care facilities, an accessibility index has been devised using weighted accessibility measures discussed in Chapter 2. It is assumed that among the three selected types of health care facilities for regular health care problems, pharmacy is the most visited, followed by GP/Surgeons clinic and finally dental clinic. Therefore, a weight of 0.5 has been assigned for all pharmacies, 0.4 for all GP/Surgeons clinics, and 0.1 for all dental clinics[1]. Accessibility index has been measured using the following weighted accessibly index equation (Liu and Engels 2012):

$$A_i = \sum_{j=1}^{3} w_j D_{ij} \text{ and } D_{ij} = \frac{d_{ij} - d_{\min j}}{d_{\max j} - d_{\min j}}$$

Where A_i = accessibility index, w_j is the weight for type *j* health care facilities, D_{ij} is the normalized shortest travel distance value for each health care facilities, d_{ij} is the measured shortest travel distance (between MB centroid to nearest health care facilities), $d_{min\ j}$ is the minimum travel distance (between MB centroid to nearest health care facilities) for a type *j* health care facilities and $d_{max\ j}$ is the maximum travel distance (between MB centroid to nearest health care facilities) for type *j* health care facilities.

3.7.3 Mapping spatial clusters

Spatial variation in accessibility to health care facilities has been measured in terms of the total number of the resident population and percentage of households which has less than 2 cars and dwellings with income of less than $499 per week using exploratory spatial data analysis techniques implemented in the ArcGIS and Geoda software environment.

[1] Weight is based on discussion with supervisors, discussion with colleagues, friends and personal experience, in terms of expected frequencies of visit to these facilities – e.g. more frequent to Pharmacies than GPs and visit to the latter is more frequent than to Dentists.

High/low clustering (Getis-Ord General G) and hot spot analysis (Getis-Ord Gi*) was undertaken using ArcGIS Spatial Statistics tools. Accessibility index and total population has been used as an input to measure overall spatial pattern and local spatial clusters of MB-based accessibility index values. Required spatial weight file was first developed in ArcGIS and then transferred into the Geoda environment to define the spatial relationships among the key variables. Hot spot analysis produced separate feature class as an output, with associated z scores (GiZScore) and statistical significance p-values (GiPValue). Whereas high/low clustering analysis produced a general summary in either a graphical format or in an HTML file.

Using ArcGIS Spatial Statistics tools, both global spatial autocorrelation trend (i.e. Moran's I) and local spatial clusters and outliers (Anselin Local Morans I) has been measured. Accessibility index and total population have been used as inputs to estimate both overall spatial pattern and local spatial cluster of MB-based accessibility index values. Likewise, spatial weights files for both high/low clustering and hot spot analysis have been used to define the spatial relationships among features. Spatial autocorrelation analysis can generate a HTML file if required. On the other hand, cluster and outlier analysis can produce feature class as an output. The feature class has the following attributes: local Moran index (LMiIndex), z-score (LMiZScore), statistical significance p-value (LMiPValue) and cluster/outlier type (COType) such as HH, LL, HL and LH as have been discussed in section 5.3 and 5.4.

Using the spatial statistics tools implanted in the Geoda environment and the required spatial weight matrix files, measures of univariate LISA can be generated in the form of cluster maps, significance maps, boxplots and Morans scatter plots. These results can be saved and exported into a shape file to be use in the ArcGIS environment for further analysis.

3.7.4 Identifying disadvantaged locations / local communities

Two approaches have been undertaken for identifying disadvantaged communities based on outputs from the hot spot analysis and cluster and outlier analysis are discussed below.

Spatial overlay analysis, union in this case, has been carried out to identify the presence of anticipated spatial clusters of low accessibility index and spatial clusters of high total population counts from hot spot analysis. Similar analysis has also been performed on results from cluster and outlier analysis and from univariate LISA analysis. Table 3-2 shows results of overlaying spatial clusters of accessibility index (**Input 1**) and spatial clusters of total population counts (**Input 2**): a hot spot of accessibility index (i.e. a cluster of high accessibility values) overlay with a hot spot of total population count (i.e. a cluster of high total population count) will result in an overall hot spot (Hot-Hot). Similarly, cold spots in accessibility index overlay with cold spots in total population count will result in overall cold spots (Cold-Cold). All other combinations are considered as no clustering or random distribution.

Table 3-2 Results of overlaying two layers of clusters from hot spot analysis

			Input 2	
	Results	**Hot**	**Cold**	**No clustering**
Input 1	Hot	Hot - Hot	Hot - Cold	Hot - No clustering
	Cold	Cold - Hot	Cold - Cold	Cold - No clustering
	No clustering	No Clustering - Hot	No clustering - Cold	No clustering - No clustering

Given the overlay results, the number of MBs, total population and other census variables can then be estimated for each cluster type.

Interpretation of overlay results from hot spot analysis is relatively straightforward, because there are only nine different possible combinations of hot, cold and not significant clusters. But interpretation of overlay results from cluster and outlier analysis and results from univariate LISA analysis are more challenging, due to more different possible combinations of various types of clusters such as HH, LL, LH, HL and not significant / no clustering (Table 3-3).

Table 3-3 Results of overlaying two layers of clusters from univariate LISA analysis or cluster and outlier analysis

		Input 2				
	Results	HH	LL	LH	HL	Not Significant
Input 1	HH	HH - HH	HH - LL	HH - LH	HH - HL	HH - Not significant
	LL	LL - HH	LL - LL	LL - LH	LL - HL	LL - Not significant
	LH	LH - HH	LH - LL	LH - LH	LH - HL	LH - Not significant
	HL	HL - HH	HL - LL	HL - LH	HL - HL	HL - Not significant
	Not significant	Not significant - HH	Not significant - LL	Not significant - LH	Not significant - HL	Not significant – Not significant

3.8 Conclusion

This chapter presents the research methodology used in this study. First a case study area with urban and rural qualities has been selected. Then spatial accessibility to health care facilities has been characterized from the user's perspective. To map spatial variation of population, health care facilities and transportation infrastructure as well as spatial variation in spatial accessibility and identify disadvantaged locations, required dataset and sources are identified. Those dataset will be collected, prepared and organized in a geodatabase. Exploratory spatial data analysis will then be conducted to better understand the spatial variation of the population, health care facilities and transportation infrastructure in the case study area. Car based shortest travel distance, shortest travel time, as well as, service areas will be derived. Weighted accessibly index is developed using car based proximity between health care facilities and their potential users. Spatial variations in access to health care faculties will be investigated using exploratory spatial data analysis and measured using local and global spatial statistics. Hot spot analysis (Getis-Ord Gi*), cluster and outlier analysis (Anselin Local Moran’s I) and univariate LISA analysis will then be performed to identify the spatial clustering of areas where spatial accessibility and total population is relatively high or low. Finally, spatial overlay (union) analyses will be conducted to identify areas with high and low accessibility clusters in relation to high and low population clusters. Overall research frame work has been presented in Figure 3-7.

Chapter 4 The Case Study Area

4.1 Introduction

This Chapter describes the case study area and the data sets used to investigate spatial accessibility to health care facilities by the local communities. First, the location, land use and localities of the study area, including are described in Section 4.2. Then, the characteristics of the population, the health care facilities and transportation system in the study area are described in Section 4.3 Section 4.4, and Section 4.5, respectively.

4.2 Location, land use and localities of the study area

The case study area is confined to the Cardinia Shire, a Local Government Area (LGA) in Victoria, Australia[1]. The shire is located between Pakenham and Tooradin, about 52 km south-east of Melbourne's central business district (CBD). The geographical location of the study area (as shown in Figure 4-1) is between latitudes 37°85´South and 38°33´ South and longitudes 145°35´East and 145°76´East. The

[1] Cardinia Shire's name is derived from the Bunurong or Wadawurrung word Kar-din-yarr, which means ‘looking to the sunrise,' or 'close to the sunrise' (Cardinia shire 2012a). The origin of the word goes back before European settlement when the Wadawurrung people would travel to the land between what are now Dandenong, Narre Warren, Pakenham and Cranbourne to meet with the Bunurong, Wurundjeri and Taungaurung people for ceremonies, trade and cultural business.

study area is about 1281 km^2 in size and has a population of 45,552 persons and 21,075 dwellings in 2006, with an average of 2.17 persons per dwelling (Australian Bureau of Statistics, 2006). Public transportation available between CBD and Cardinia Shire include a few bus services along the roads and a metropolitan train that runs to Pakenham. It takes about one and half hours in the peak time and about one hour in off peak by car along the Monash freeway / Princess Highway from the CBD to reach this outer fringe area of Melbourne.

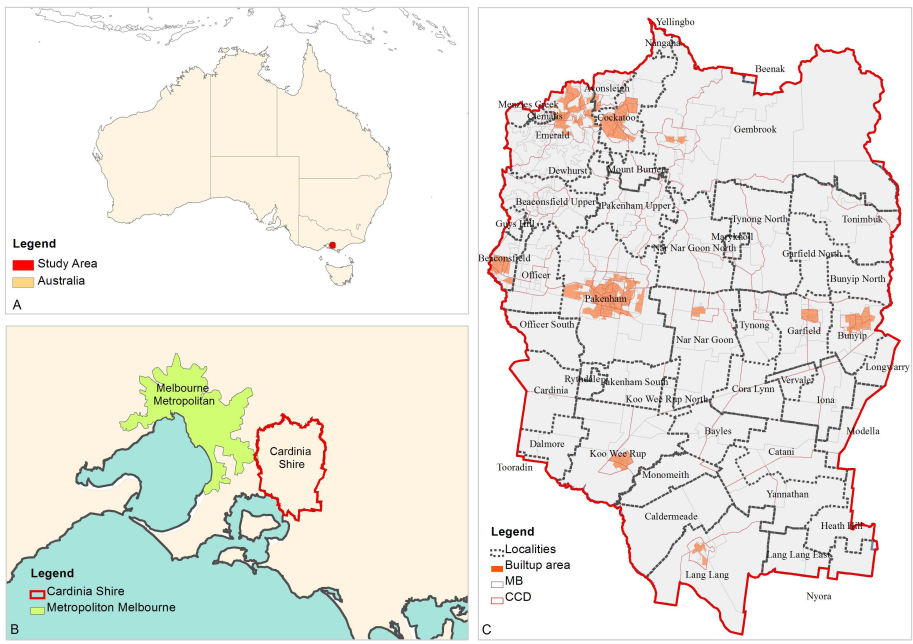


Figure 4-1 The location (A), extent (B), localities and built-up areas (C) of the case study area

The Shire of Cardinia has 17 built-up areas (Figure 4-1C). There are also many small remote towns to be found within the study area. The entire Cardinia Shire area has been divided into 74 census collection districts (CCDs) by the Australian Bureau of Statistics (ABS) (see Figure 4-1C). A CCD is defined as an area that one census collector can cover, deliver and collect census forms in a specified period. On average, there are about 150 to 250 dwellings per CCD. In 2007, the ABS introduced the Mesh Block (MB) boundaries for the whole of Australia. On average, there are about 20-30 dwellings in a MB. In 2007, some basic population and dwelling counts and the dominant land use category, from the 2006 census, have been released on Mesh Blocks.

Cardinia Shire is located in an urban fringe zone of the Melbourne metropolitan area. The land use of the Shire is predominantly for agriculture. Other land use types include park lands, water bodies, and small amount of lands for residential, commercial, industrial, commercial, educational and hospital/medical uses (Figure 4-2 and Figure 4-3).

As the result of statewide local government reform, the Shire came into being on 15 December 1994, by merging the Shire of Pakenham with rural sections of the Shire of Sherbrooke and City of Cranbourne (Australian Bureau of Statistics 1995)[1].The areas within the current Shire boundary were once belonged to the Cranbourne and Berwick Municipal Districts, which were incorporated in 1860 and 1862, respectively.

[1] Berwick and areas closer to Dandenong, split away from the Shire of Berwick, with the remainder being renamed Shire of Pakenham (Arnall & Jackson. 1992).The Shire of Fern Tree Gully, later Shire of Sherbrooke, split away in 1889 and included areas to the east of Melbourne. In 1973, the City of Berwick, including Berwick and areas closer to Dandenong, split away from the Shire of Berwick, with the remainder being renamed Shire of Pakenham.

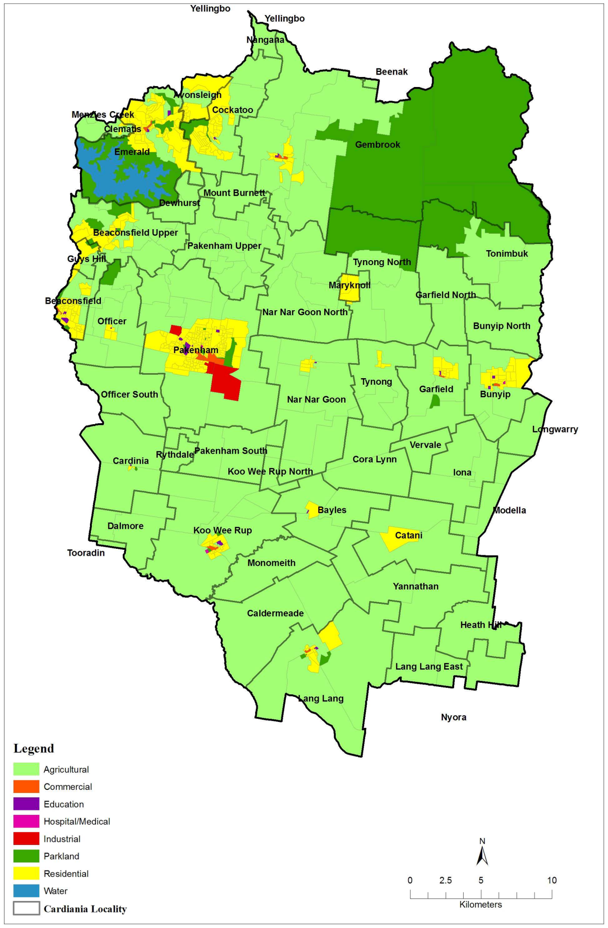


Figure 4-3 Land use map of the study area

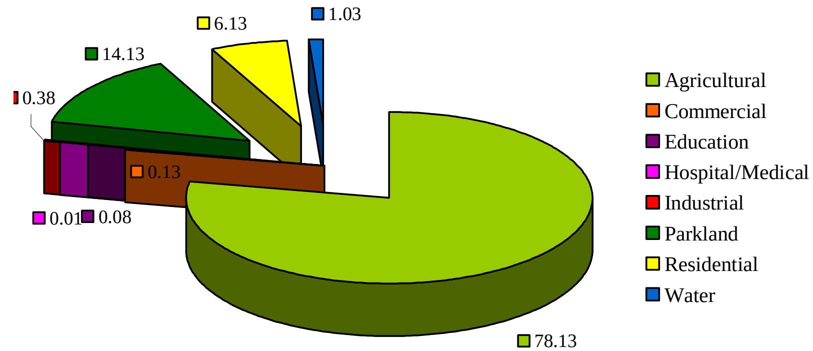


Figure 4-2 Land use category of Cardinia Shire

Before the European settlement, the Wadawurrung, Bunurong, Wurundjeri and Taungaurung people were used to live and conduct their affairs in the study area. Europeans settled in this area about 150 years ago. Since European settlement this area has become more populated. According to the ABS 2006 census, there are about 60,000 inhabitants living in this area, including 22,685 male residents and 22,855 female residents.

4.3 The population

The study area has a number of interesting demographic characteristics (see Table 4-1) including the spatial distribution of the population. Figure 4-4 shows the MB level population density within the study area. It can be seen that only a few MBs located in large towns are densely populated. Using residential address points and the clustering method developed by Maillet et al (2009) similar spatial patterns of population density can be revealed (Figure 4-4).

According to the 2006 census statistics, the residents of Cardinia Shire were engaged in a number of different employment sectors. The leading employment sectors were retail (12.2%), manufacturing (12.1), construction (11 %), health care and social assistance (7.9%). Interestingly, only about 8.8% is engaged in the agriculture and forestry industry (ABS 2006), given that agriculture is the dominant land use type in the area. There are 27,203 people employed, but among which only 32.9% are able to find work within the shire. In contrast, more than 55% of the total working population travels outside of the shire for work (Figure 4-5). About 60.6% of the total population is employed full time and 32.4% is employed part time; about 66.4% of the population aged 15 and older are in the labour force and 28.7% are not (ABS 2006).

Table 4-1 Demographic profile of the Cardinia Shire

Enumerated data	2006			2001			Change 2001 to 2006
	Number	(%)	Melbourne Statistical Division %	Number	(%)	Melbourne Statistical Division %	
Enumerated population, including overseas visitors							
Total population (a)	45,404	100	100	56,270	100	100	10,866
Males (a)	22,655	49.9	48.9	27,897	49.6	49	5,242
Females (a)	22,749	50.1	51.1	28,373	50.4	51	5,624
Overseas visitors	99	0.2	0.8	118	0.2	0.8	19
Enumerated population, excluding overseas visitors							
Total population (b)	45,305	100	100	56,151	100	100	10,846
Males (b)	22,607	49.9	49	27,838	49.6	49	5,231
Females (b)	22,698	50.1	51	28,313	50.4	51	5,615
Population characteristics							
Indigenous population	175	0.4	0.4	234	0.4	0.4	59
Australian born	36,689	81	65.7	45,008	80.2	64.2	8,319
Overseas born	6,398	14.1	28.6	7,980	14.2	29	1,582
Australian citizens	40,963	90.4	86.7	50,042	89.1	84.5	9,079
Australian citizens aged 18+	27,948	61.7	65.4	34,692	61.8	64.2	6,744
Institutional population	365	0.8	2.3	487	0.9	2.5	122
Age structure							
Infants 0 to 4 years	3,527	7.8	6.4	4,256	7.6	6.3	729
Children 5 to 17 years	10,382	22.9	17.4	12,462	22.2	16.6	2,080
Adults 18 to 64 years	27,275	60.2	64.1	34,119	60.8	64.5	6,844
Mature adults 65 to 84 years	3,679	8.1	10.7	4,699	8.4	10.9	1,020
Senior citizens 85 years and over	442	1	1.4	617	1.1	1.6	175
Households and dwellings							
Owned	5,861	35.2	38.7	5,592	26.6	30.4	-269
Purchasing	6,324	37.9	26	9,495	45.2	31.8	3,171
Renting	2,267	13.6	21.1	3,381	16.1	22.5	1,114
Households (occupied private dwellings)	15,568	--	--	19,670	--	--	4,102
Persons counted in households	45,039	--	--	55,782	--	--	10,743
Average household size (persons)	2.89	--	--	2.84	--	--	-0.06
Total Dwellings	21,025	100	100	16,673	100	100	4,352

(Source: Shire of Cardinia 2011)

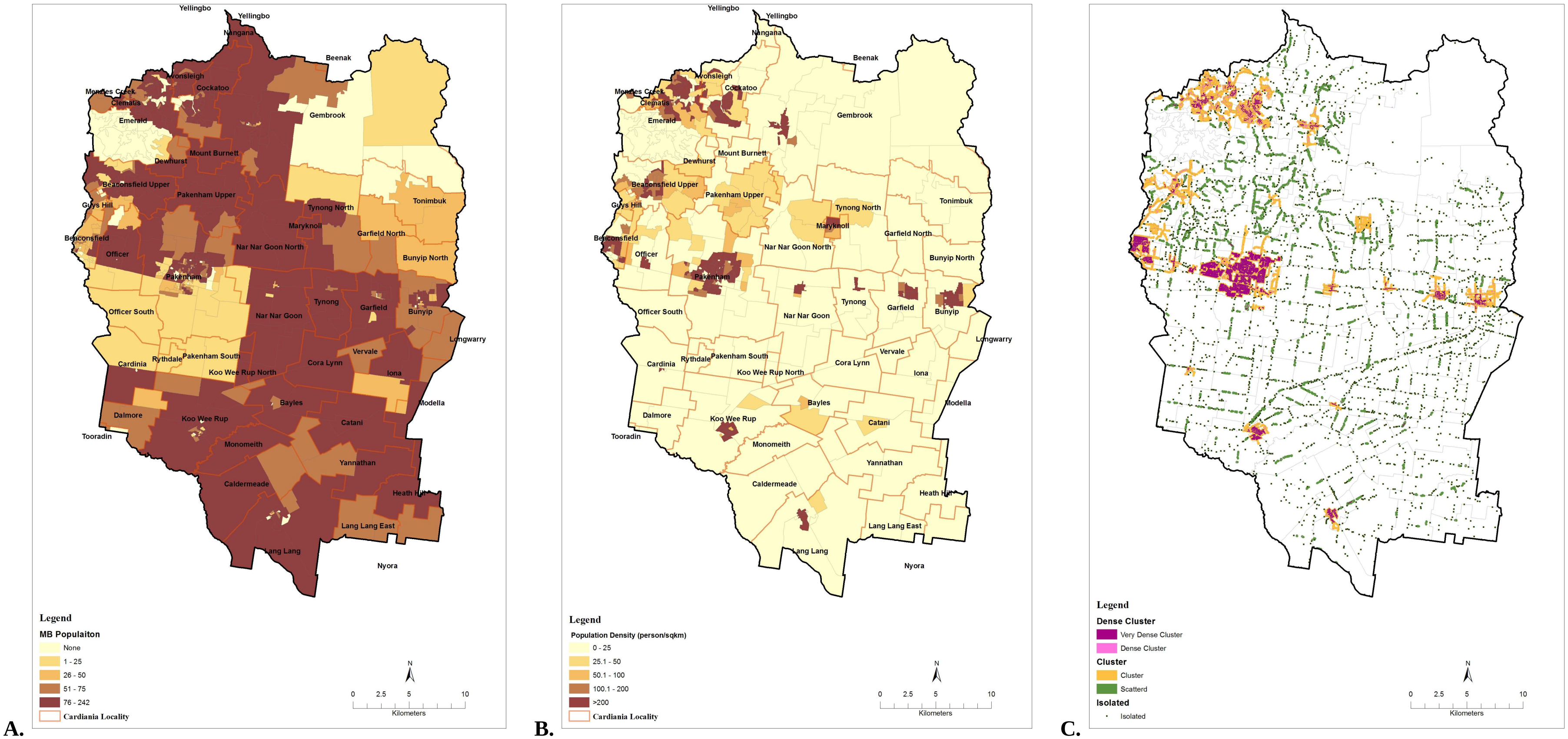
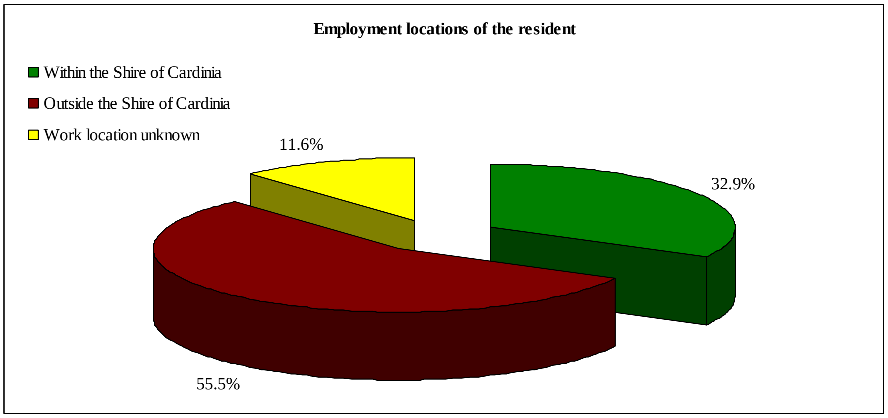


Figure 4-4 MB population distribution (A) MB population density (B), residential address clusters (C) in the study area



Source: Australian Bureau of Statistics, Census of Population and Housing, 2006.

Figure 4-5 Employment locations of the residents

The 2006 ABS census data shows that more than 90% of households within the study area owned at least one car, about 26.9% of households have only one vehicle, and about 31.2 % of total households do not have more than one vehicle. In contrast, about 42.1% of total households owned two cars; 22.7% owned three cars or more, and about 63.7% of household owns more than or equal to two cars. In the study area, there are about 24.1% (n= 4,081) families with income less than $499 a week (ABS, 2006), Table 4-2 shows percentage of unemployed total population aged over 15, and Table 4-3 shows percentage of unemployed female population aged over 15: about 31.9 % (n= 11,074) are unemployed and more than half of them (n= 6,914) are females. These statistics implies that regardless their economic strength, the local communities have a heavy dependency on car (instead of public transport) based travelling. It can be argued that with a combination of absence of car and unemployment, a large proportion of the population may have low mobility.

Table 4-2 Percentage of total unemployed population aged over 15

% population	Number of MB	Total population	Percentage of total population (Age >15, n=34,717)
None/No data	88	0	0
0.1 - 5	137	1,786	5.14
5.1 - 10	346	7,517	21.65
10.1 - 15	12	288	0.83
> 15	54	1,483	4.27
Total	**637**	**11,074**	**31.90**

Table 4-3 Percentage of total unemployed female population aged over 15

% population	Number of MB	Total female population	Percentage of female population (Age >15, n=17,576)
None/No data	87	0	0
0.1 - 5	0	0	0
5.1 - 10	13	96	0.55
10.1 - 15	322	3,276	18.64
> 15	215	3,542	20.15
Total	**637**	**6,914**	**39.34**

The study area has a relatively small population size in 2006, but a forecast indicates that the population could be three times more than current population within next two decade (Table 4-4).

Table 4-4 Demographic profile of the Cardinia shire

Summary data	Forecast year		
	2006	**2020**	**2030**
Total population	58,541	107,121	141,659
Resident population in non-private dwellings	431	883	1,221
Resident population in private dwellings	58,109	106,237	140,439
Households	20,527	39,877	53,439
Dwellings	21,280	41,341	56,006
Average household size	2.83	2.66	3

(Source: Cardinia Shire council 2011)

4.4 Health care facilities

Within the case study there are a number of different private and public health care facilities available, but there has no hospitals. Altogether, 184 health care facilities were identified within the study area (Table 4-5). Some of these services like Community Health Care and Maternal & Child Health are public funded; other services like Pharmacy and Dental are private funded.

Table 4-5 Available health care facilities within the case study area

Type	Number of service	Funding
Pharmacy	18	Private
Naturopaths	16	Private
GP	34	Public
Community Health Care	2	Public
Dental	15	Private
Maternal & Child Health	13	Public
Surgery	35	Public & private
Alternative Health Services	6	Public & private
Pathology	3	Public & private
Optometrists	7	Public
Mental Health	5	Private
Massage Therapy	17	Private
Chiropractor	13	Private
Total	**184**	**-**

Three types of primary health care services are selected in this study, including pharmacies, GP/Surgeons clinic and dentists. It is assumed that for primary health care people go to the nearest pharmacy to get basic medicine more often than go to a GP/Surgeons clinic to get health check-ups, medical examination, consultation and prescriptions, and that dental service is another important form of primary health care. The ratio of health care facility to population is 1:3,310 for pharmacy, 1:1,758 for GP/Surgeons clinic and 1:3,751 for dental clinic (Table 4-6), which are much lower compared to the national benchmarks. For example, the national GP to population ratio is 1:1400 (Victorian Divisions Network, 2011).

Table 4-6 Available health care facilities (Pharmacy, GP/Surgeon clinic and Dentist) within the study area

Types	Total (n=64)	Ratio (Persons / health care facility)
Pharmacy	17	3310
GP/Surgeon clinic	32	1758
Dentist	15	3751

There are 64 heath care facilities for the three primary health care services selected for this study, including 17 pharmacies, 32 GP/Surgeons clinics and 15 dental clinics. Most of these health care facilities are located in Pakenham (n=28), Emerald (n=18) and Bunyip (n=6). The rest of the health care facilities are distributed in Beaconsfield, Koo Wee Rup, Lang Lang, Beaconsfield Upper, Cockatoo and Garfield (Table 4-5 and Table 4-6). Among the 49 localities within Cardinia Shire, only 9 localities have health care facilities (Table 4-7).

Table 4-7 Available health care facilities (Pharmacy, GP/Surgeon clinic and Dentist) within the study area by locality name.

Name	Pharmacy	GP/Surgeon Clinic	Dentist	Total
Pakenham	6	16	6	28
Koo Wee Rup	1	0	2	3
Beaconsfield Upper	1	0	0	1
Emerald	1	11	6	18
Beaconsfield	3	0	1	4
Lang Lang	1	1	0	2
Garfield	1	0	0	1
Cockatoo	1	0	0	1
Bunyip	2	4	0	6
Total	**17**	**32**	**15**	**64**

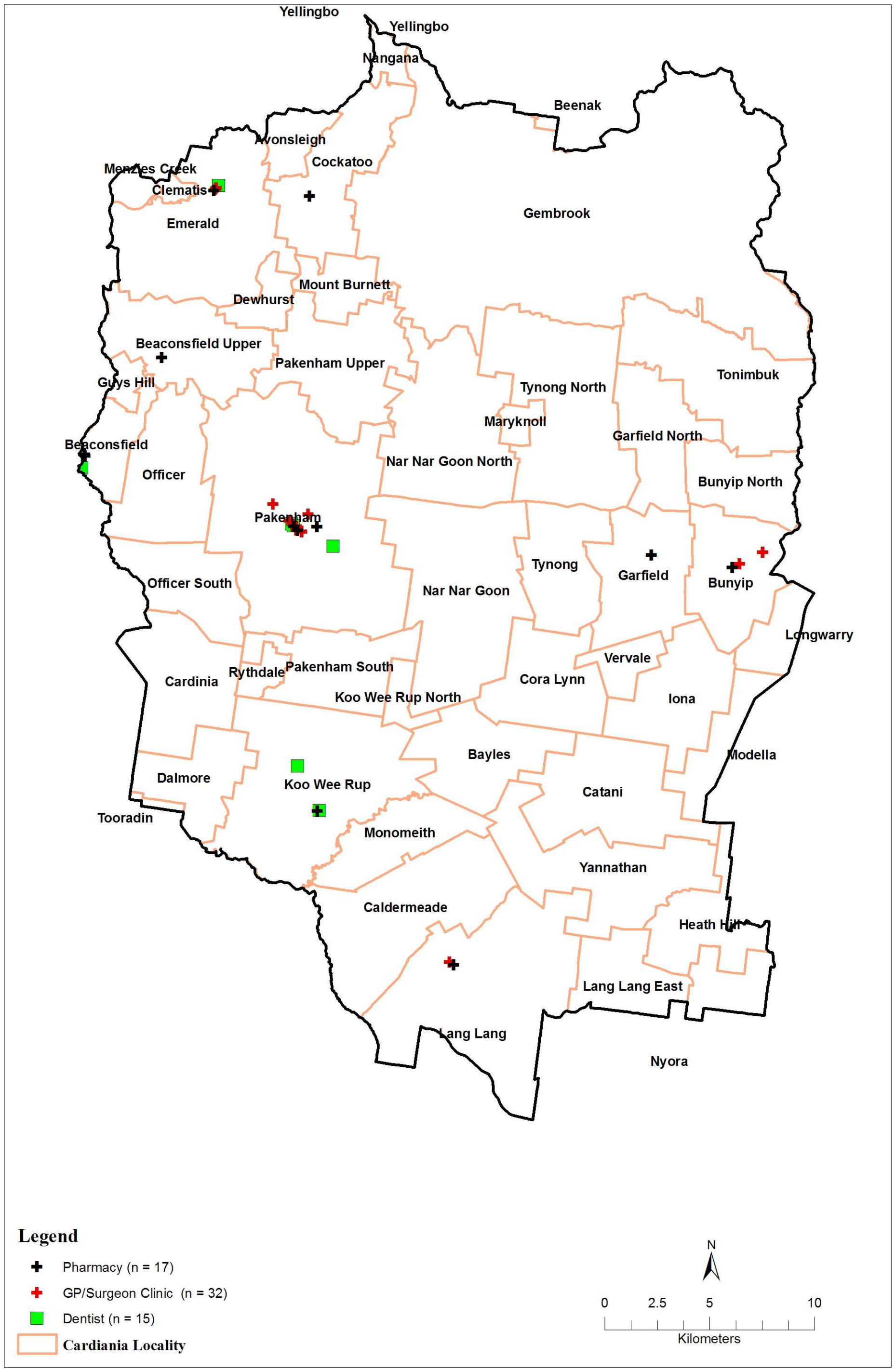


Figure 4-6 Distribution of health care facilities (Pharmacy, GP/Surgeons clinic and dental clinic) within the study area

4.5 Transportation

The road infrastructure is unevenly distributed in the study area (Figure 4-7). The southern part of the study area is mainly agricultural with only a few small towns. The Princess freeway enters the study area near Beaconsfield and Officer, going through Pakenham, Nar Nar Goon, Tynong and Garfield and exits at Bunyip. Another highway enters at Koo Wee Rup, runs along the Bass Coast, and exits at Lang Lang. In contrast, the central west and north western parts of the study area is relatively well populated, have larger towns and many roads. These roads have different speed limits and different traffic conditions throughout the day. There are Freeways, Highways, roads with townships and local roads. The speed limits for the road transportation network are listed in Table 4-8. Altogether, there are approximately 3,362.5 km roads within the study area with an average road density of 2.63 km roads / km^2.

Table 4-8 Speed limits for the road network

Road Types	Speed Limits (Km/hr)*	Road Length (km)
Freeway	100	68.4
Highway	80/90	84
Roads	50	1,453.6
Roads within township	40	1,756.5

(Source: VicRoads 2012)

Public transportation is inadequate for the population living in this area. There are two major public transportation systems available within this area, train and bus. Three different types of train services are available within the study area: Metropolitan train, Regional train and the tourist Puffing Billy train. The metropolitan train runs from early morning to late night throughout the week. Train services between Melbourne CBD and Dandenong run approximately every 15 minutes Monday to Friday and every 20 minutes on the weekends. Evening service operates every 20 to 30 minutes (Public Transport Victoria, 2012). Train service from Dandenong to Pakenham is less frequent. During the weekend, the frequency of train service is once in a 60-90 minutes. In average, it takes about 80 minutes by train to reach Flinders street station in the Melbourne CBD from Pakenham, after about 30 stops.

There are 11 bus routes connecting the main localities within the study area, but most of the bus routes are located in the North West part of the study area (Figure 4-7). These bus services mainly connect to Pakenham, Mount Burnet, Cockatoo, Emerald, Beaconsfield and Officer. Some of the busses only run in the morning, some run once in two hours and some busses have different routes on weekdays and weekends (Public transport Victoria, 2011).

This preliminary analysis reveals that the local communities have inadequate public transport (train and bus) services and have to depend heavily on their cars for travelling, as implied by the statistics of car ownership summarized in Table 4-9and shown in Figure 4-8. According to ABS 2006 census, in the study area, 4.3% of dwellings (n=673) do not have any car, 26.9% of dwelling (n=4,183) have one car, 31.2% of dwellings have less than 1 car (n=4,856), and 63.7% of dwelling (n=9,922) have two or more cars.

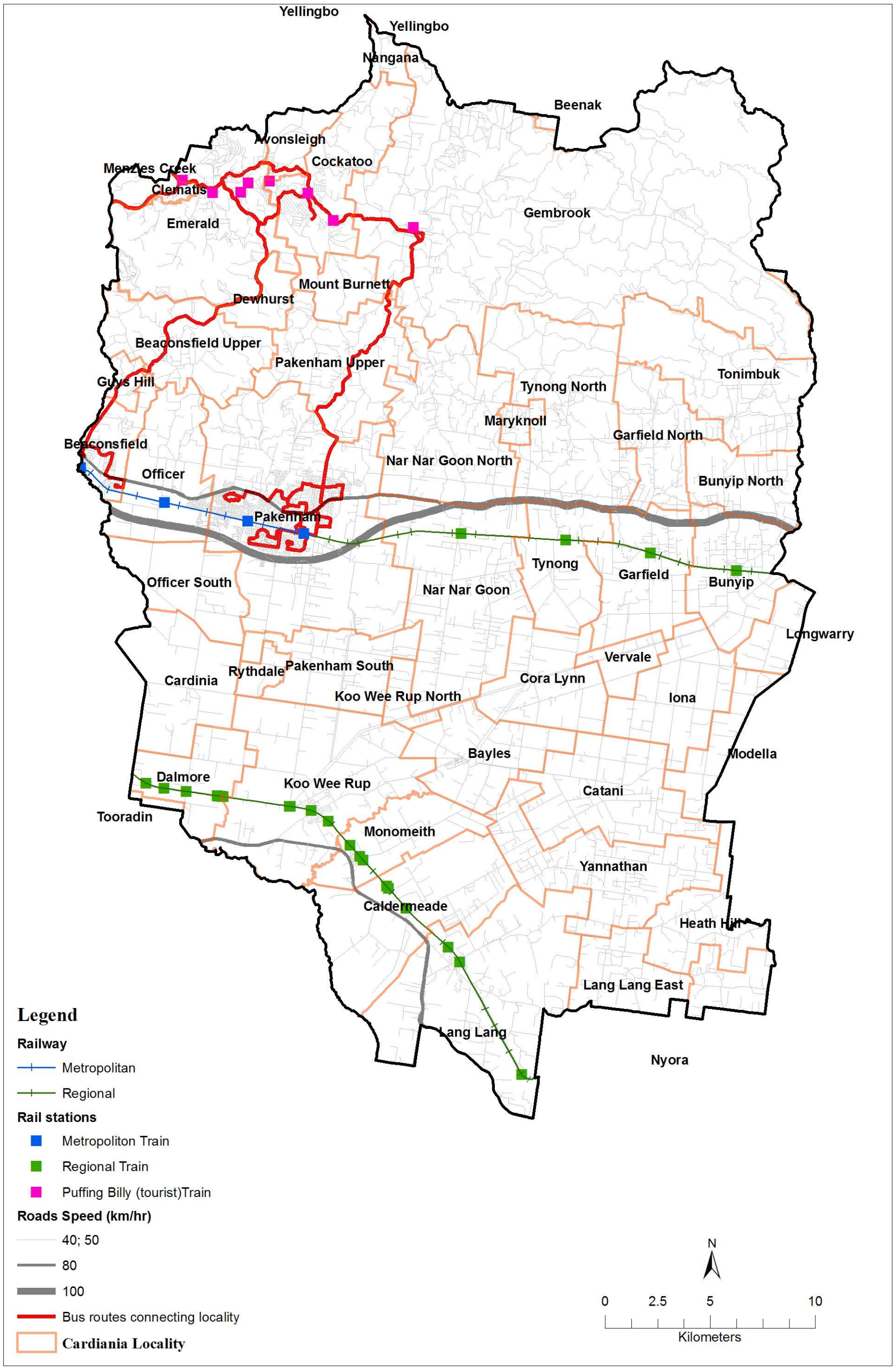
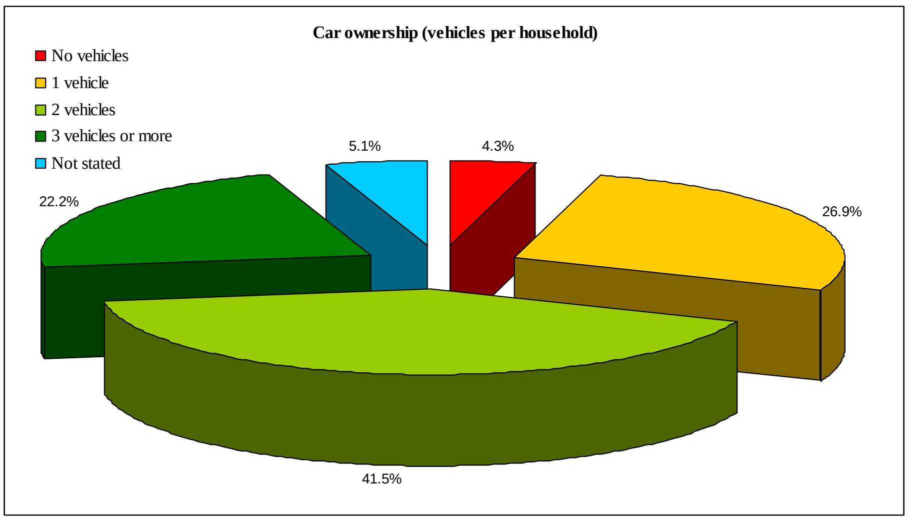


Figure 4-7 Road infrastructure in the study area

Table 4-9 Proportion of dwellings with car owndership in the Shire

Enumerated data	Number	Percentage	Number	Percentage
No vehicles	673	4.3	4,856	31.2
1 vehicle	4,183	26.9		
2 vehicles	6,465	41.5	9,922	63.7
3 vehicles or more	3,457	22.2		
Not stated	793	5.1	793	5.1
Total	**15,571**	**100**	**15,571**	**100**



Source: Australian Bureau of Statistics, Census of Population and Housing, 2006.

Figure 4-8 Structure of car ownership (vehicles per household dwellings) in the Shire

Statistics on travel mode of journey to work by the resident population of the study area shows that only 4% (n= 1,059) of the populations are using public transport to travel to work, 66.4% (n= 17,812) of the population travel to work using car (see Table 4-10), suggesting that inadequate public transport services are driving the population towards using their own motor vehicles.

Table 4-10 Travel (mode of journey) to work by the residents of the study area.

Travel to work	Cardinia Shire	
(includes multi-mode journeys)	2006	
Enumerated data	**number**	**%**
Train	956	3.6
Bus	103	0.4
Tram or Ferry	11	0.0
Taxi	10	0.0
Car - as driver	17,812	66.4
Car - as passenger	1,197	4.5
Truck	574	2.1
Motorbike	136	0.5
Bicycle	72	0.3
Walked only	556	2.1
Other	265	1.0
Worked at home	1,760	6.6
Did not go to work	2,844	10.6
Not stated	513	1.9
Total	**26,809**	**100**

(Source ABS, 2006)

The spatial distribution of two types of car ownership (i.e. < 2 cars / dwelling and >= 2 cars / dwelling) are shown in Figure 4-9 and Figure 4-11. The spatial clustering of hot spots and cold spots (based on Getis-Ord Gi*) of these two types of car ownership are clearly shown in Figure 4-10 and Figure 4-12.

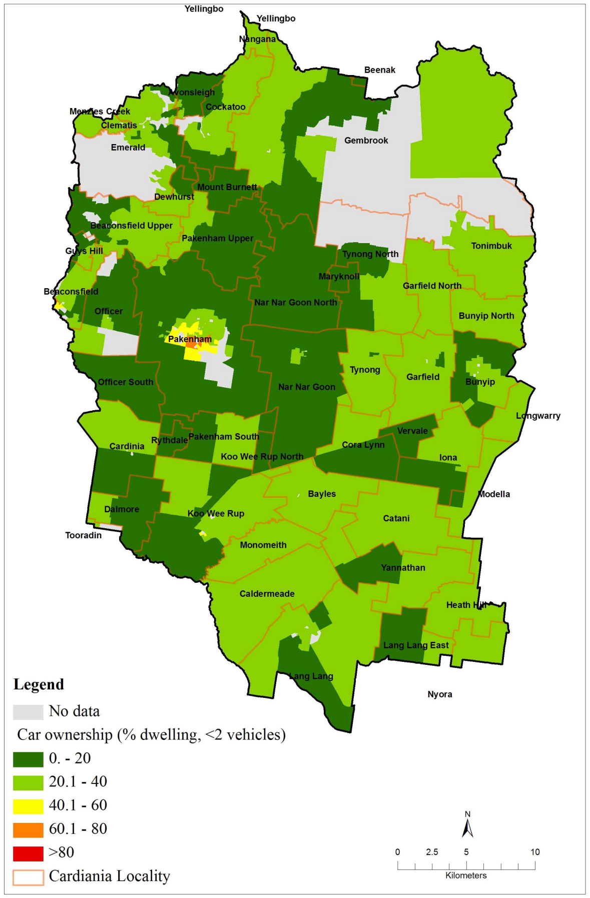


Figure 4-9 Car ownership (<2 vehicles /household dwellings) of the study area

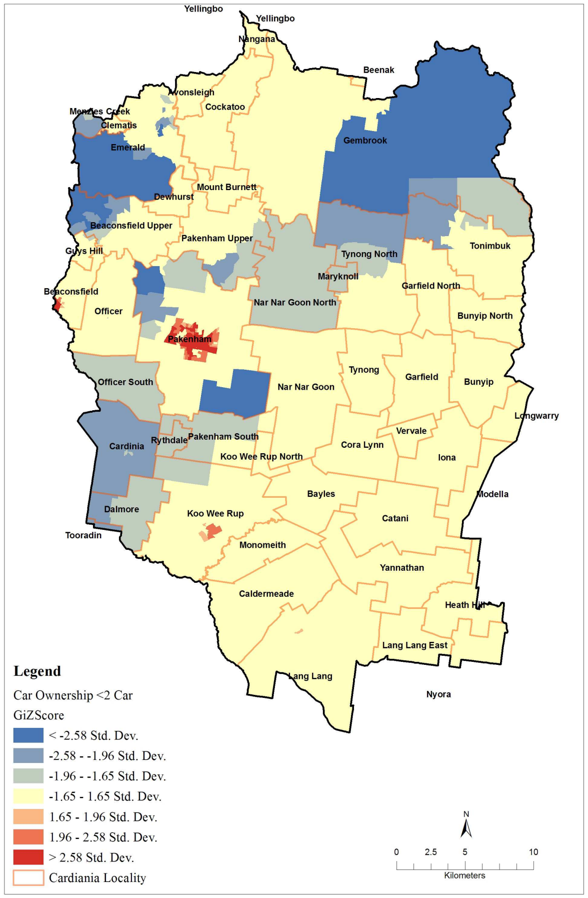


Figure 4-10 Clustering of car ownership (<2 vehicles /household dwellings) of the study area

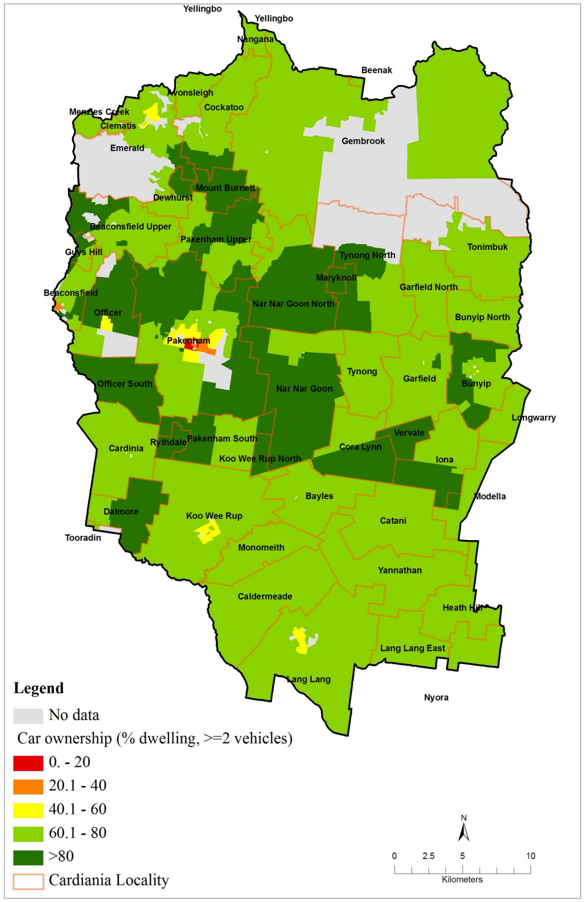


Figure 4-11 Car ownership (>=2 vehicles /household dwellings) of the study area

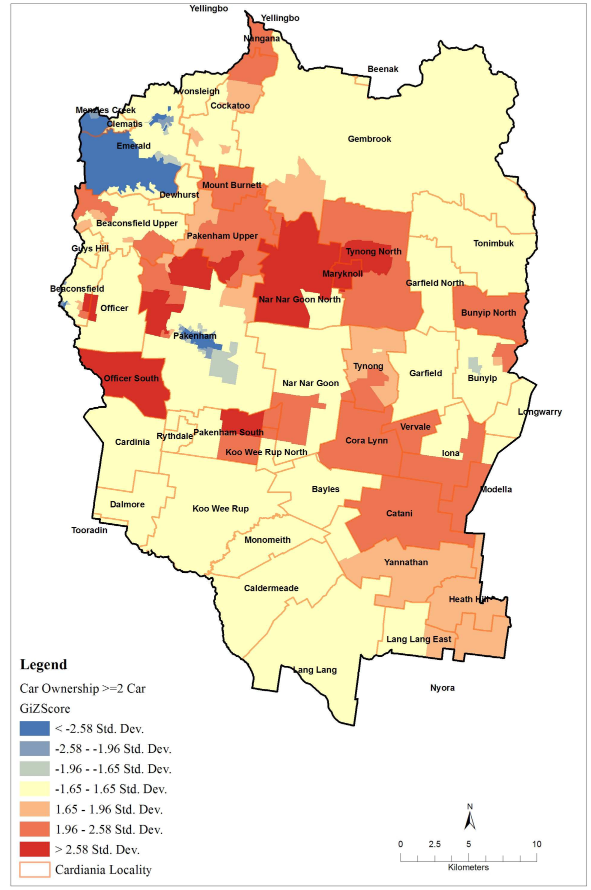


Figure 4-12 Clustering of car ownership (>=2 vehicles /household dwellings) of the study area

4.6 Conclusion

In this Chapter the study area and some of its basic characteristics are presented. There are 17 pharmacies, 32 GP/Surgeon clinics and 15 dentists within the study area, with a relative lower facility to population ratio of 1:3,310 for pharmacy, 1:1,758 for GP/Surgeons clinic and 1:3,751 for dental clinic. Among the 49 localities within the study area, only 9 localities have one or a few of the selected three types of health care facilities, the rest 40 localities do not have any such health care facilities. Many of those localities are also not well connected with public transport services. Residents at those localities are depending on their cars for travel. The availability of the public transport services within some selected localities (e.g. Bunyip, Tonimbuk, Gembrook, Nar Nar Goon, Koo Wee Rup, Lang Lang) are very limited.

About 69% of the total population aged >15 are in the workforce, and more than 55% of these employed population travel outside the study area for work and 96 % of them use their own travel arrangement to reach their workplaces. Both car ownership and family income statistics suggest that many non-working populations, including young mother with dependent children and senior citizens, especially the unemployed females in the study area, have a very poor accessibly to health care facilities because they are left behind by their working family members without a car.

Spatial variations in accessibility to health care facilities and disadvantaged local communities within the study area are presented in Chapter 5.

Chapter 5 Spatial Accessibility to Health Care Facilities and Disadvantaged Locations / Local Communities

5.1 Introduction

This Chapter presents research findings made from this study with a discussion of their practical significance. The results are presented in three sections: Section 5.2 presents spatial accessibility to health care facilities measured in terms of travel distance, travel time, and service areas, as well as spatial variation of the integrated accessibility index; Section 5.3 presents results from spatial clustering analysis performed on both the total population and on the integrated spatial accessibility index values; Section 5.4 presents disadvantaged locations / local communities identified on the basis of spatial overlay analysis.

5.2 Spatial accessibility to health care facilities

Spatial accessibility to health care facilities measured and characterized using two related approaches: (1) in terms of the shortest travel distance between health care facilities and the locations of their potential users at the Mesh Block (MB) level, as well as the respective population and their relevant socio-economic characteristics within zone of specified travel distances (Section 5.2.1); and (2) in terms of the shortest travel time between health care facilities and the locations of their potential users at the Mesh Block (MB) level, as well as associated population and their relevant socio-economic characteristics within zones of specified travel time. Service catchment areas based on shortest travel distance and associated number of MBs and populations are also determined (Section 5.2.2). Spatial distribution of accessibility index scores for pharmacies, GP/Surgeon's clinics and dental clinics, both individually and in combination, have also been presented in this section (Section 5.2.3).

5.2.1 Travel distance to closest health care facilities

Travel distance to the closest health care facilities from MB centroids (as proxies of local communities) via the road network is measured using the Closest Facility tool in ArcGIS according to procedures described in Section 3.7.2. Table 5-1shows the minimum, maximum, average and standard deviation of travel distances (measured in metres) to the nearest health care facilities from the MB centroids in the study area. It can be seen that the total length of travel distance to the closest health care facilities ranges between 12.6 m and 31.4km. Some resident have to travel over 20km or even more than 30km to access a pharmacy, GP/Surgeons clinic or a dental clinic. In average, the residents of the Cardinia Shire were required to travel over 3km (3228.6m) for a pharmacy, close to 6km (5848.2m) for a GP/Surgeon's clinic, and over 6km (6187.6m) for a dental clinic.

Table 5-1 Travel distance (m) from MB centroid to nearest health care facilities

Health care facilities	Minimum (m)	Maximum (m)	Average (m)	SD (m)
Pharmacy	12.6	24,478.3	3,228.6	3,348.9
GP/Surgeon	22.9	26,996.1	5,848.2	4,861.7
Dentist	22.6	31,393.4	6,187.6	6,275.6

Table 5-1 indicates that a large proportion of those health care facilities are not easily accessible by walking. As the availability of public transport services are low in the study area the local residents have to organize their own transport in order to access the health care facilities.

Figure 5-1, Figure 5-2 and Figure 5-3 show the shortest travel distances and routes from MB centroids to nearest health care facilities and travel distance based service areas for pharmacies, GP/Surgeon clinic and dental clinic. Figure 5-1 shows that areas within easy walking access (<1200m) are very limited (highlighted in mars red, cantaloupe and orange colours) and that a large proportion of the study area have a travel distance greater than 5km to nearest pharmacy and therefore are accessible only feasibly by cars. Figure 5-2 shows that there were only four localities with GP/Surgeon clinics, therefore only locations within the 4 limited areas (highlighted mars red, cantaloupe and orange colour) have easy access to GP by walking. Large proportion of the study area is beyond 10km from the nearest GP/Surgeons clinics. Dental services are also available only to four localities and significant proportion of the study area is beyond 10km from the nearest dental clinic, and in the eastern half of the study area there is no dental service facilities available (Figure 5-3). The maps shown that spatial accessibility to health care facilities as measured by travel distance is relatively high in the localities of Pakenham, Koo Wee Rup, Beaconsfield Upper, Emerald, Beaconsfield, Lang Lang, Garfield, Cockatoo and Bunyip.

Table 5-2 and Table 5-3 show the estimated number of MBs and the cumulative percentage of MBs located within zones of specified distances from health care facilities. Travel distance can be separated into acceptable walking distance (≤ 1.2km) and beyond acceptable walking distance (>1.2km). The tables show that: (1) only 5.2% of the MBs (n= 33) are located within 0.4km from nearest pharmacies, 4.1% (n= 26) from the nearest GP/Surgeons and 3.0% (n= 19) from the nearest dental service facilities; (2) there are 16.2% (n= 103), 10.8% (n= 69) and 8.9% (n= 57) of MBs located within 0.8km of pharmacies, GP/Surgeons and dentists, respectively; and (3) only 29.8% (n= 190), 21.2% (n= 135) and 16% (n= 102) of the MBs are located within a tolerable walking distance (≤ 1.2km). Table 5-3 shows that in average over 70% of the MBs having travel distances beyond 1.2km from the nearest health care facilities. Specific service areas based on travel distance from MB centroids are presented in Figure 5-2 and Figure 5-3.

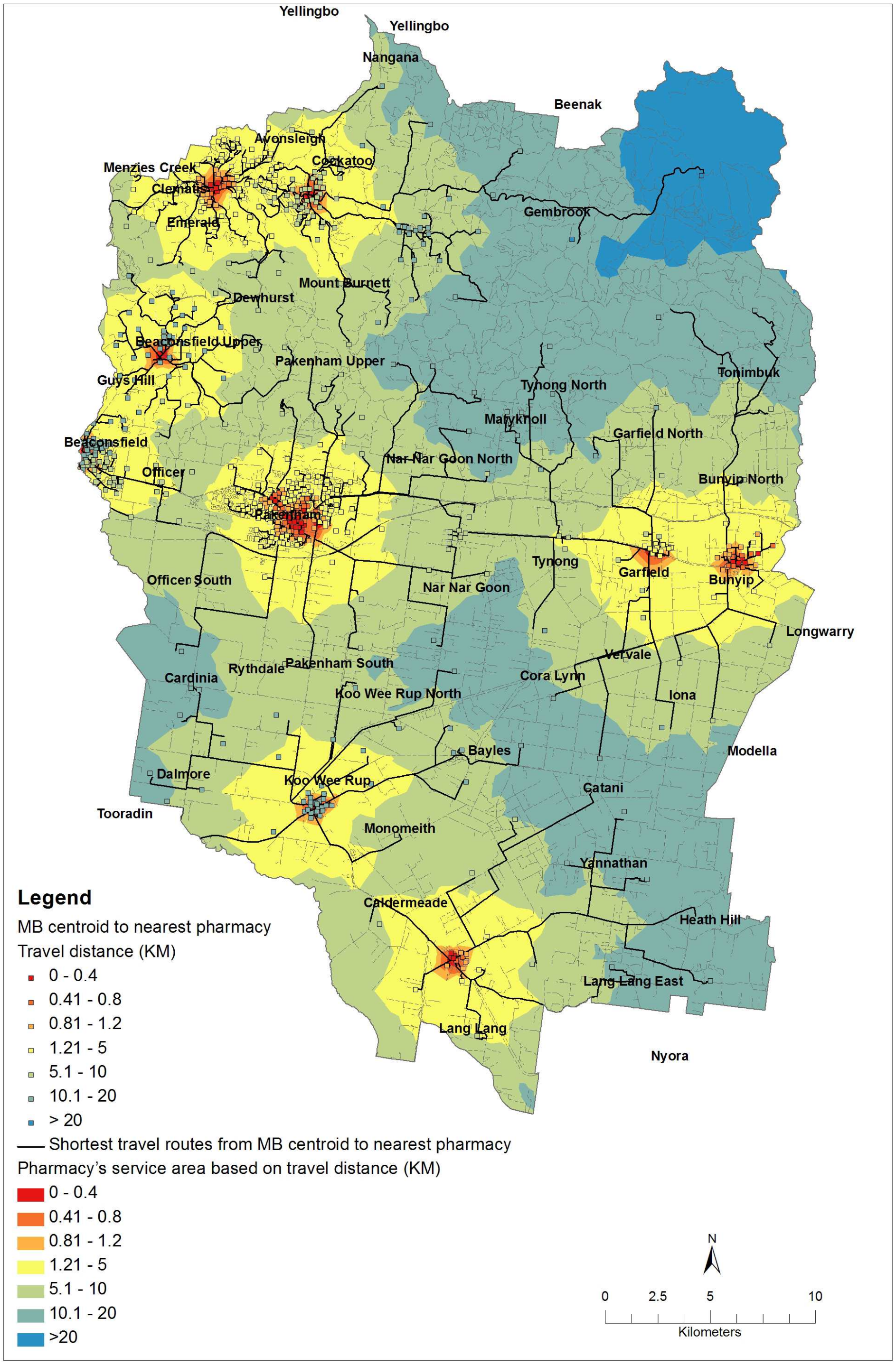


Figure 5-1 Shortest travel routes and travel distances from MB centroids to nearest pharmacies and travel distance based service areas for pharmacies.

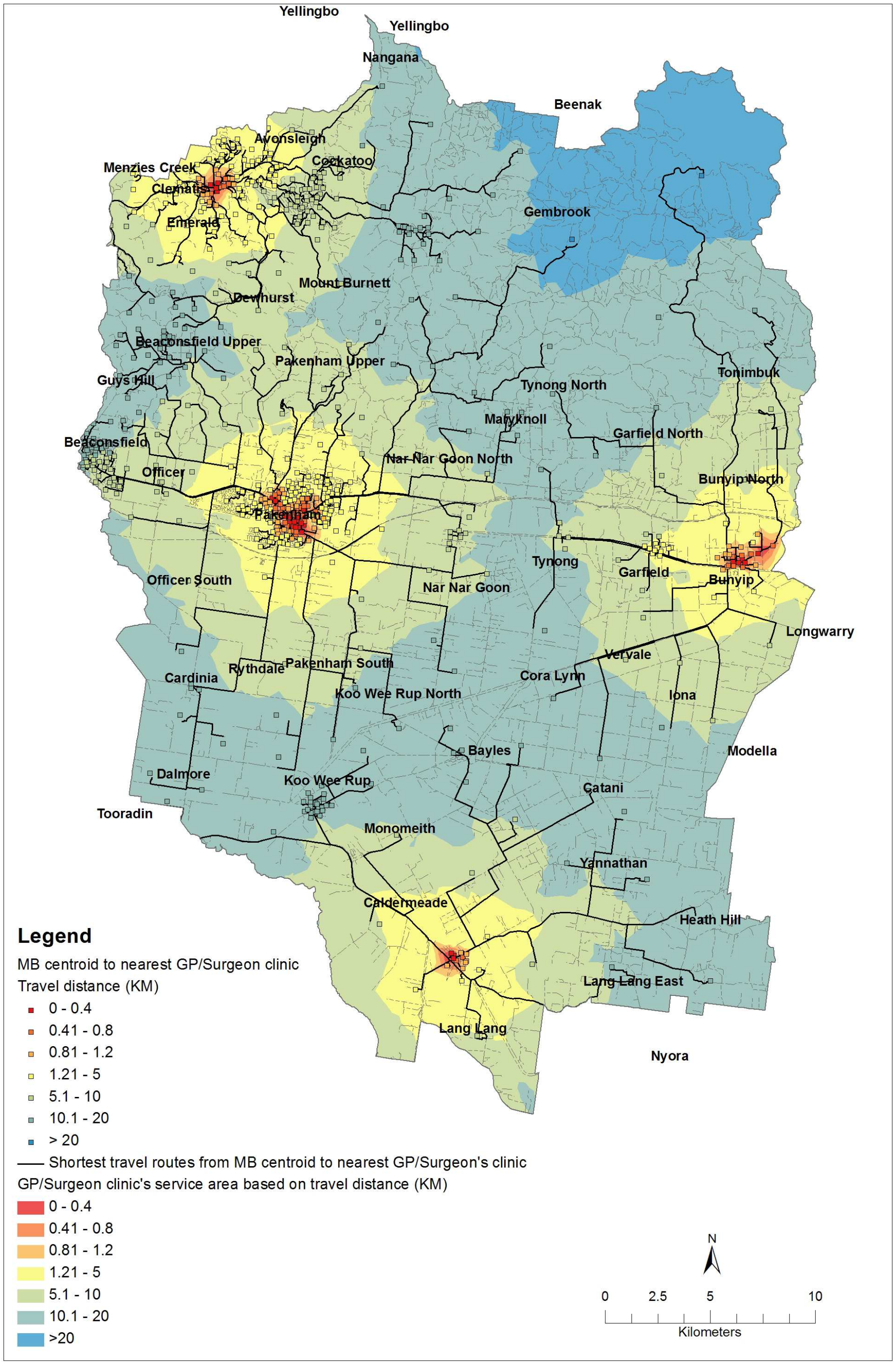


Figure 5-2 Shortest travel routes and travel distances from MB centroids to nearest GP/Surgeons clinics and travel distance based service areas for GP/Surgeons clinics.

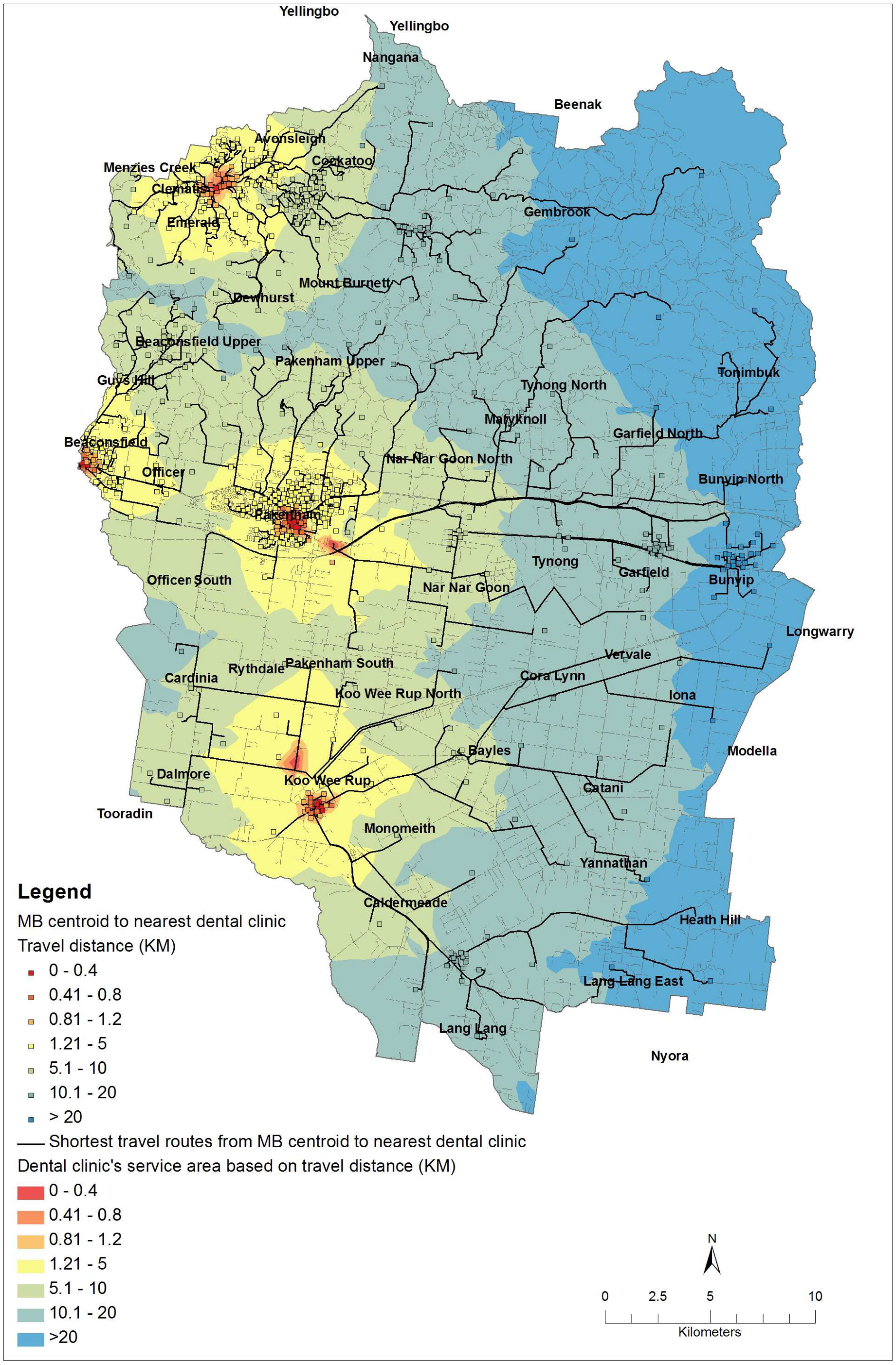


Figure 5-3 Shortest travel routes and travel distances from MB centroids to nearest dental clinics and travel distance based service areas for dental clinics.

Table 5-2 Number of MBs within specified travel distance (km)

Types	MBs within specified travel distance (km)							
	0-0.4	0.4-.08	0.8-1.2	1.2-5	5-10	10-20	>20	Total
Pharmacy	33	70	87	316	90	40	1	637
GP/Surgeons clinics	26	43	66	189	142	169	2	637
Dentists	19	38	45	260	140	96	39	637

Table 5-3 Cumulative percentage of MBs within specified travel distance (km)

Types	MBs within specified travel distance (km)						
	0-0.4	0.4-.08	0.8-1.2	1.2-5	5-10	10-20	>20
Pharmacy	5.2	16.2	29.8	79.4	93.6	99.8	100
GP/Surgeons clinics	4.1	10.8	21.2	50.9	73.2	99.7	100
Dentists	3.0	8.9	16.0	56.8	78.8	93.9	100

This study also established that only a small proportion of the population can feasibly reach their nearest health care facilities by walking, and a large proportion of the population do not reside within a tolerable walking distance from their nearest health care facilities. The estimated cumulative total population and the estimated cumulative percentage of total population within specific travel distances from the nearest health care facilities are summarized in Table 5-4 and Table 5-5 and illustrated in Figure 5-4. According to the 2006 ABS census data, there are 27.5 % (12536 persons), 20.3% (9241 persons), and 12.9% (5867 persons) of the population reside within a tolerable walking distance of 1.2km from the nearest pharmacies, GP/Surgeons clinics and dental clinic respectively, and majority of the population have to drive or use public transportation to reach their nearest health care facilities.

Table 5-4 Cumulative total population within specified distance (km)

Types	Population within specified distance (km)						
	0.4	**0.8**	**1.2**	**5**	**10**	**20**	**>20**
Pharmacy	1,730	6,133	12,536	35,297	42,233	45,527	45,552
GP/Surgeons clinic	1,306	4,623	9,241	23,078	33,537	45,527	45,552
Dentist	719	2,863	5,867	23,533	34,223	42,885	45,552

Table 5-5 Cumulative percentage of population within specified distance (km)

Types	Percentage of population within specified distance (km)						
	0.4	**0.8**	**1.2**	**5**	**10**	**20**	**>20**
Pharmacy	3.8	13.5	27.5	77.5	92.7	99.9	100
GP/Surgeons clinic	2.9	10.1	20.3	50.7	73.6	99.9	100
Dentist	1.6	6.3	12.9	51.7	75.1	94.1	100

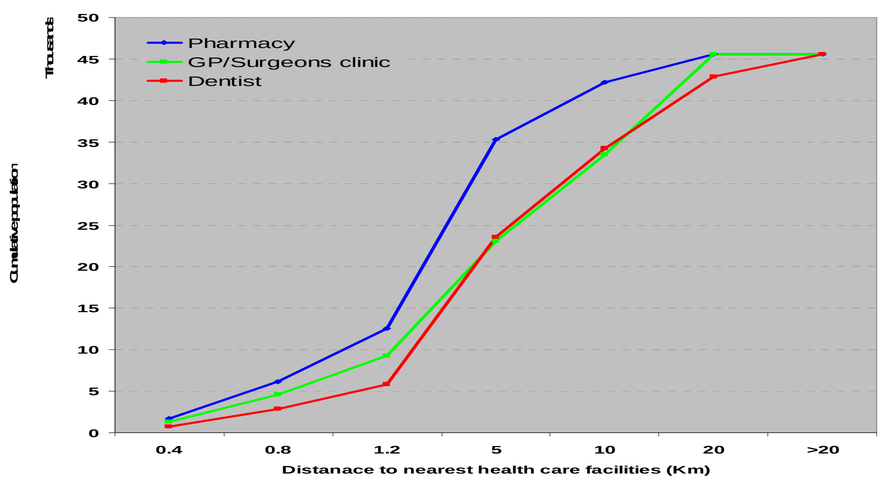


Figure 5-4 Estimated resident population within specified travel distance

Figure 5-5, Figure 5-6 and Figure 5-7 show the spatial distributions of MBs (and associated localities) with travel distances to nearest healthcare facilities that are below or above the mean travel distances (which are listed in Table 5-1), and Table 5-6 and

Table 5-7 summarize the corresponding numbers and cumulative percentages of MBs and population. It is worth to note that within the limited extent of the area below mean travel distance, it contains in average over half (55.4% or 352 MBs) of the total MBs (637 MBs) and over half (52% or 23722 persons) of the total population (45552 persons).

According to the 2006 ABS census data, about 31.2% of the total populations in the Shire are identified as dependent population (including unemployed or school going children), 11.4% of the total dwellings are identified as low income dwellings, and 22.9% of the total dwellings have less than 2 cars. Percentages of the dependent population, low income dwellings, and dwellings with <2 cars that are residing within MBs within or beyond mean travel distances to nearest heath care facilities are summarized in Table 5-8. It can be seen that in average although large proportions of the dependent population (63%), low income dwelling (68%), and dwellings with less than 2 cars (72%) are residing in MBs within mean travel distances to closest health care facilities, there are still significant proportions of the dependent population (37%), low income dwelling (32%), and dwellings with less than 2 cars (28%) are residing in MBs with relatively poor spatial accessibility (or beyond mean travel distances) to closest health care facilities.

Table 5-6 Numbers and percentages of MBs that are within or beyond mean travel distances to nearest heathcare facilities

Health care facilities	<Mean	%	>Mean	%
Pharmacy	311	48.82	326	51.18
GP/Surgeons clinic	350	54.95	287	45.05
Dentist	397	62.32	240	37.68

Table 5-7 Numbers and percentages of persons residing in MBs that are within or beyond mean travel distances to nearest heathcare facilities

Health care facilities	<Mean	%	>Mean	%
Pharmacy	20,422	44.83	25,130	55.17
GP/Surgeons clinic	24,892	54.65	20,660	45.35
Dentist	25,853	56.75	19,699	43.25

Table 5-8 Percentage of dependent population, low income dwellings, and dwellings with <2 car located within or beyond mean travel distances to nearest heath care facilities

	% of dependant population			% of low income dwelling			% of dwelling with <2 car		
	Below Mean	Above Mean	Total	Below Mean	Above Mean	Total	Below Mean	Above Mean	Total
Pharmacies	22.5	8.7	31.2	8.8	2.6	11.4	19.9	3.1	22.9
GP/Surgeons clinics	18.1	13.1	31.2	7.2	4.3	11.4	14.4	8.6	22.9
Dentists	18.5	12.6	31.2	7.2	4.2	11.4	15.1	7.8	22.9

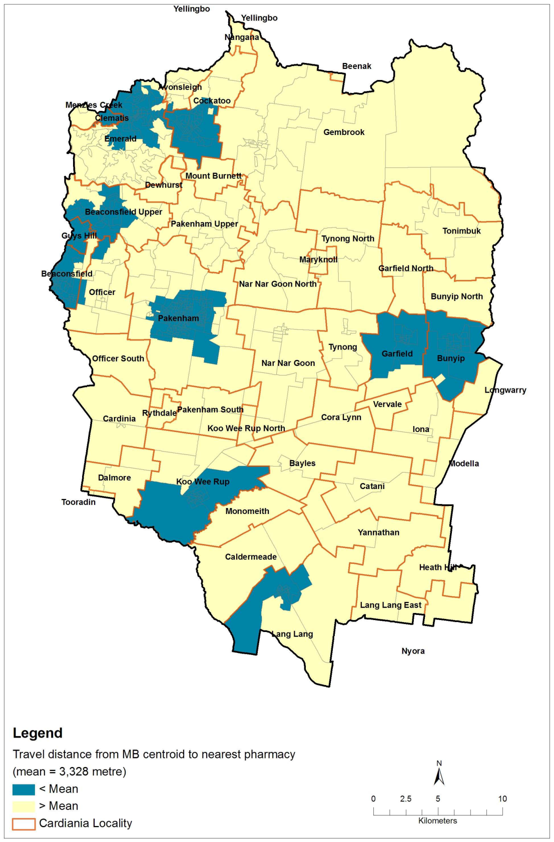


Figure 5-5 Extents of localities within or beyong mean travel distance (= 3,328m) from MB centroids to nearest pharmacies

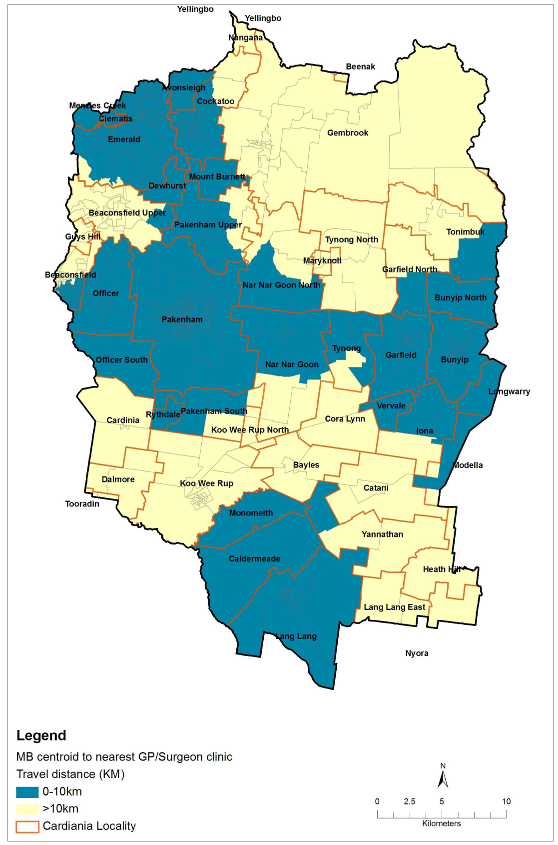


Figure 5-6 Extents of localities within or beyond mean travel distance (= 5,848m) from MB centroids to nearest GP/Surgeons clinic

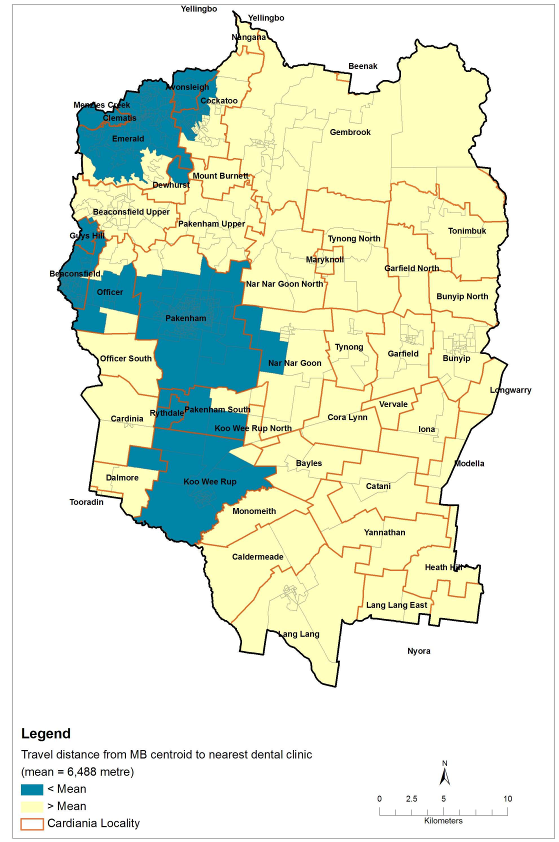


Figure 5-7 Extents of localities within or beyond mean travel distance (= 6,488m) from MB centroids to nearest dental clinic

Figure 5-8, Figure 5-9 and Figure 5-10 show the spatial extents of localities with travel distances below or above 10km to nearest pharmacies, GP/Surgeons clinics and dental clinics respectively. Table 5-9 summarizes number of MBs (based on Table 5-2) and Table 5-10 summarizes percentages of the population that located within or beyond 10km of travel distance from their nearest health care facilities. It can be seen that over 25% of the population (more than 11,000 persons) have to travel more than 10km to reach their closest GP/Surgeons clinic or dental clinic and over 7.5% of the population (more than 3,000 persons) need to travel more than 10km to visit their nearest pharmacy.

Table 5-9 Estimated number of MBs below and above 10km of travel distance from nearest health care facilities

Health care facilities	<10	%	>10	%
Pharmacy	596	93.56	41	6.44
GP/Surgeons clinic	470	73.78	167	26.22
Dentist	500	78.49	137	21.51

Table 5-10 Estimated total populaiton below and above 10km of travel distance from nearest health care facilities

Health care facilities	<10	%	>10	%
Pharmacy	42,076	92.37	3,476	7.63
GP/Surgeons clinic	33,655	73.88	11,897	26.12
Dentist	33,974	74.58	11,578	25.42

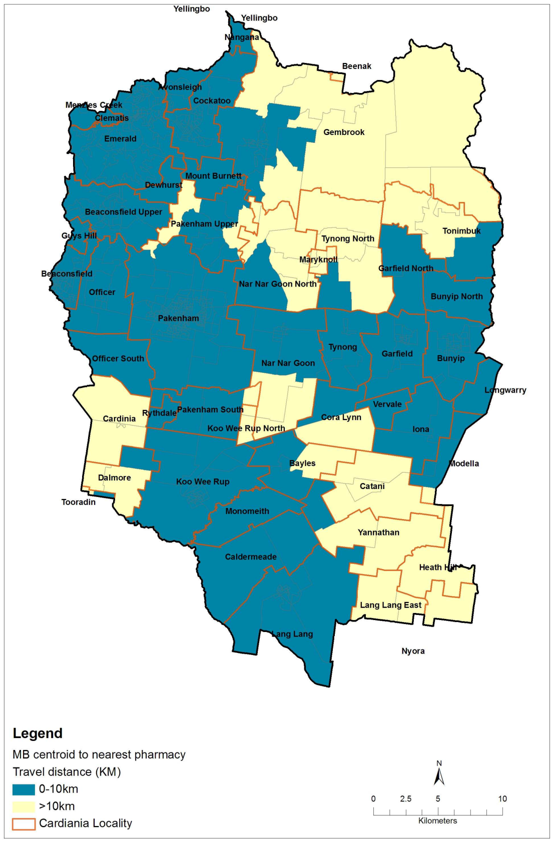


Figure 5-8 Extents of localities within or beyond 10km of travel distance from MB centroids to nearest pharmacies

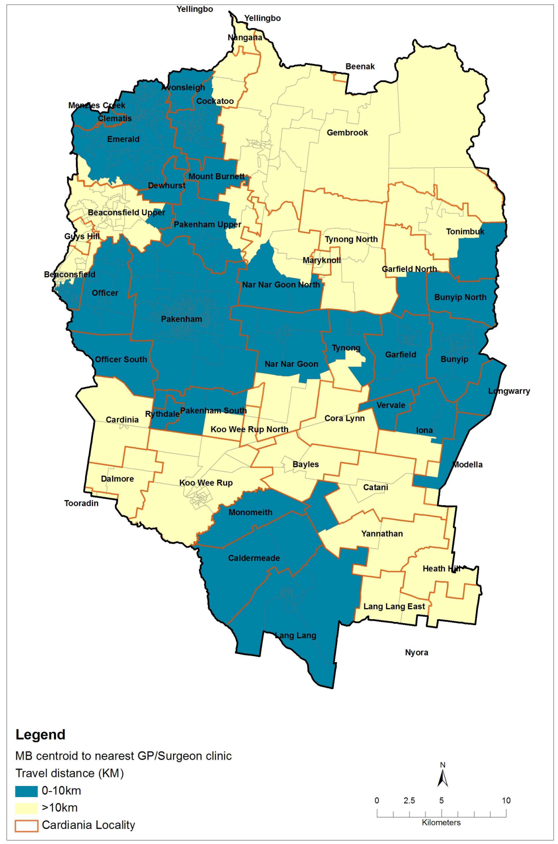


Figure 5-9 Extents of localities within or beyond 10km of travel distance from MB centroids to nearest GP/Surgeons clinics

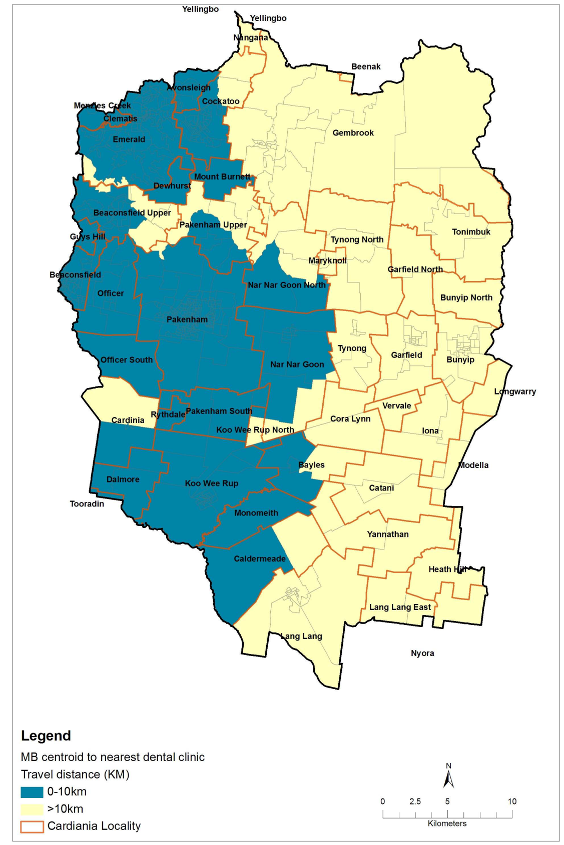


Figure 5-10 Extents of localities within or beyond 10km of travel distance from MB centroids to nearest dental clinics

Percentages of dependent population, low income dwellings and dwellings with less than 2 cars located within or beyond 10km of travel distance to nearest heath care facilities are summarized in Table 5-11. It can be seen that in average very large proportions of the dependent population (81%), low income dwelling (83%), and dwellings with less than 2 cars (85%) are residing in MBs within mean travel distances to closest health care facilities, and there are also certain proportions of the dependent population (19%), low income dwelling (17%), and dwellings with less than 2 cars (15%) are residing in MBs with relatively poor spatial accessibility (or beyond mean travel distances) to closest health care facilities.

Table 5-11 Percentages of dependent population, low income dwellings and dwellings with <2 cars located within and eyond 10km of travel distance to nearest heath care facilities

	% of dependant population			% of low income dwelling			% of dwelling with <2 car		
	Below 10km	**Above 10km**	**Total**	**Below 10km**	**Above 10km**	**Total**	**Below 10km**	**Above 10km**	**Total**
Pharmacy	29.1	2.1	31.2	10.8	0.6	11.4	21.9	1.0	22.9
GP/Surgeons clinics	23.4	7.7	31.2	9.0	2.4	11.4	18.1	4.8	22.9
Dentists	23.5	7.6	31.2	8.7	2.7	11.4	18.3	4.6	22.9

5.2.2 Travel (driving) time to closest health care facilities

Travel (driving) time (measured in minutes) to the closest health care facilities from MB centroids via road network is derived from the measured travel distances according to procedures described in Section 3.7.2. Table 5-12 shows the minimum, maximum, average and standard deviation of the travel (driving) time to the closest health care facilities. It can be seen that, it takes about 4 minutes to reach the nearest pharmacies, over 6 minutes to reach the nearest GP/Surgeons clinics or dental clinic, and in average, it takes more than 5 minutes to drive to reach the nearest health care facilities.

Table 5-12 MB centroid to nearest health care facilities travel time (minutes)

Health care facilities	Minimum (min)	Maximum (min)	Average (min)	SD (min)
Pharmacy	0.02	31.24	3.91	3.93
GP/Surgeon clinics	0.03	34.40	6.45	5.36
Dentists	0.03	38.78	6.57	5.86

Shortest travel routes and spatial variations in travel (driving) time from MB centroids to nearest pharmacies, GP/Surgeons clinics and dental clinics and corresponding service areas are presented in Figure 5-11, Figure 5-12, and Figure 5-13, respectively. These maps show similar spatial patterns in spatial accessibility to health care facilities, as shown in the travel distance based maps (Figure 5-1, Figure 5-2, Figure 5-3).

Number and cumulative percentages of MBs located within specified travel (driving) time are summarized in Table 5-13 and Table 5-14. In average, about 60% of the MBs are located within 5 minutes' driving to nearest health care facilities, and residents in about 20% of the MBs have to drive more than 10 minutes to reach their closest health care facilities. It should be noted that spatial accessibility indicated by travel (driving) time may not represent actual spatial accessibility of the residents in the study area since many residents may not have a car or may not be able to drive a car at the time they need to visit a specific health care facility.

Table 5-13 Number of MBs within specified travel (driving) time (minutes)

Types	**MBs within specified time (minutes)**				
	5	**10**	**15**	**20**	**>20**
Pharmacy	488	90	47	10	2
GP/Surgeons clinics	308	172	110	41	6
Dentists	350	125	97	46	19

Table 5-14 Cumulative percentage of MBs within specified travel (driving) time (minutes)

Types	**Cumulative percentage of MBs within specified travel time (min)**				
	5	**10**	**15**	**20**	**>20**
Pharmacy	76.6	90.7	98.1	99.7	100
GP/Surgeons clinics	48.4	75.4	92.6	99.1	100
Dentist	54.9	74.6	89.8	97.0	100

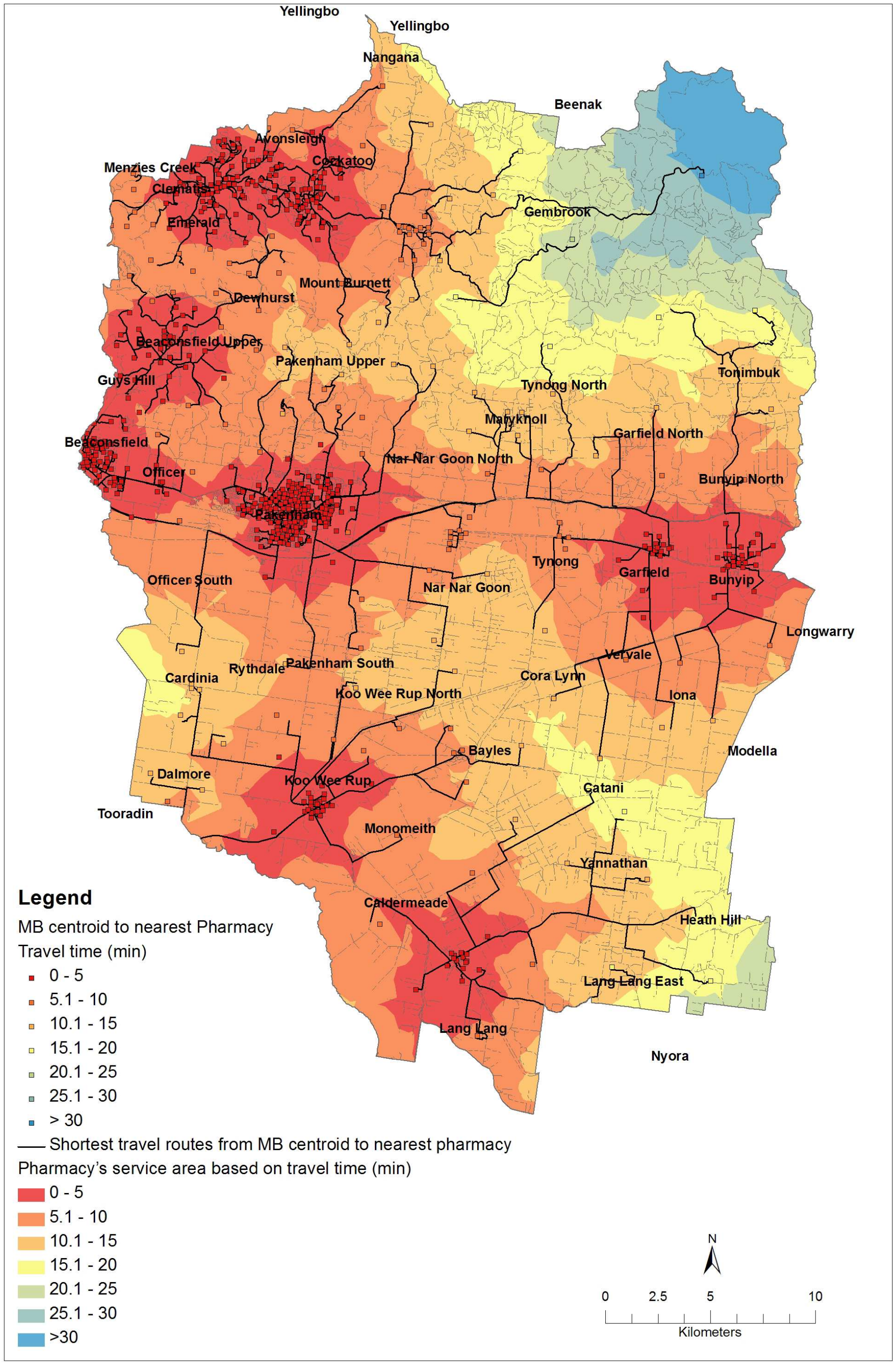


Figure 5-11 Shortest travel routes and travel (driving) time from MB centroids to nearest pharmacy and travel (driving) time based service areas for pharmacies

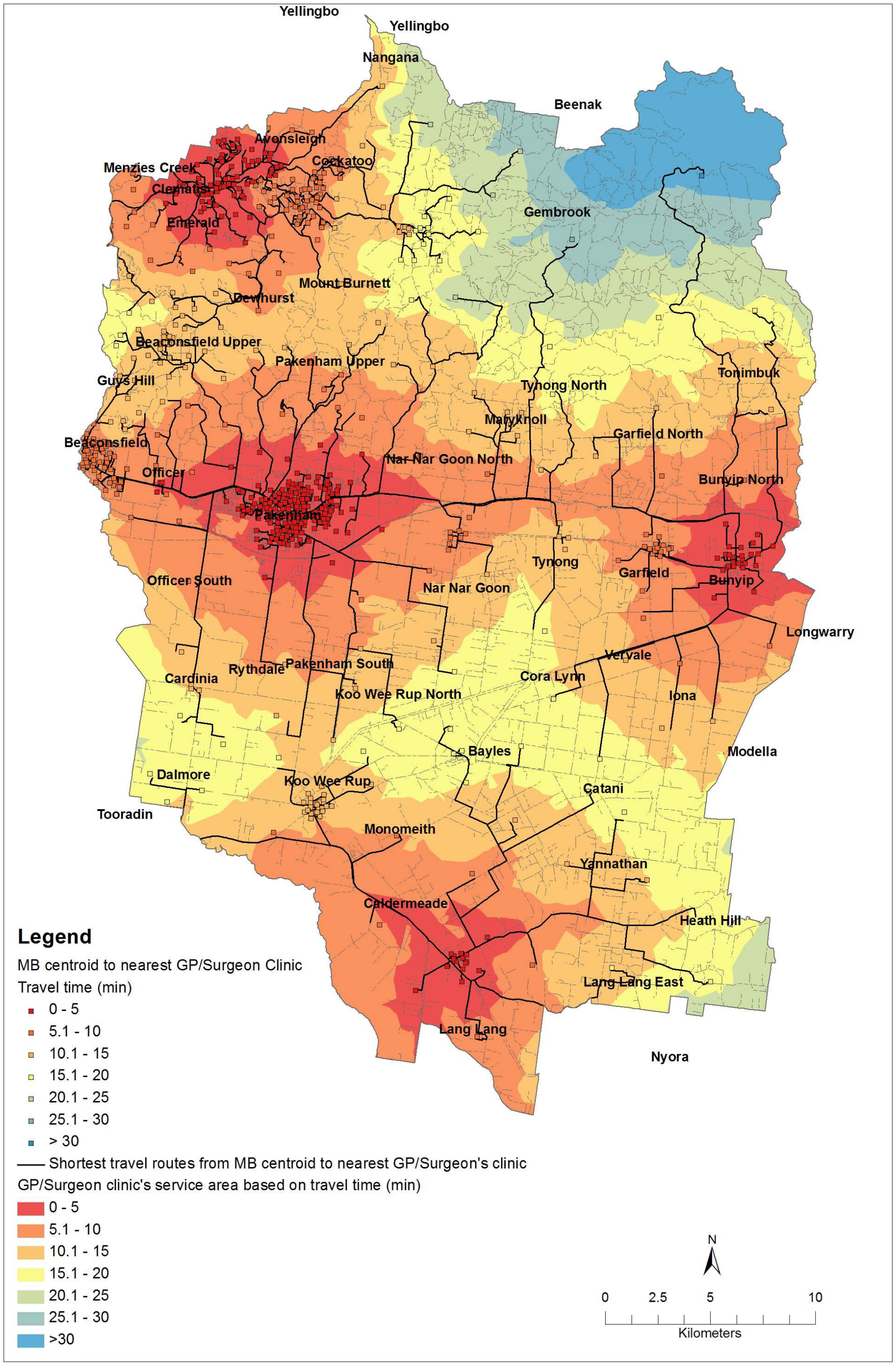


Figure 5-12 Shortest travel routes and travel (driving) time from MB centroids to nearest GP/Surgeon clinic and travel (driving) time based service areas for GP/Surgeons clinics

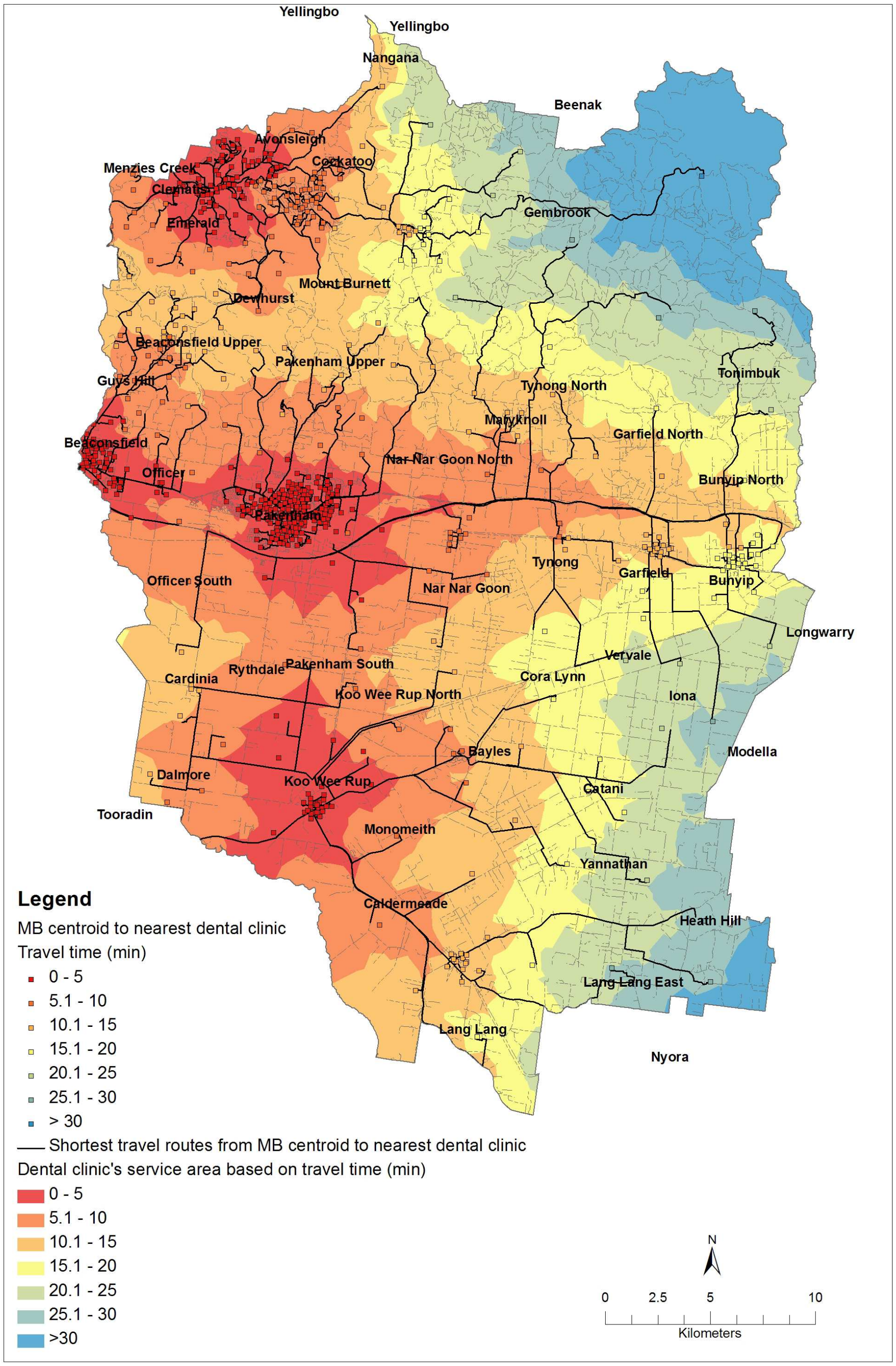


Figure 5-13 Shortest travel routes and travel (driving) time from MB centroids to nearest dental clinic and travel (driving) time based service areas for dental clinics

Spatial extents of travel (walking) time of 5*m*, 10*m*, and 15*m* (equivalent to travel distance of 400m, 800m and 1,200m respectively) to nearest health care facilities are shown in Figure 5-14. It is clear that only a small proportion of the study area in the 9 localities that have one or a few of the selected health care facilities (i.e. Pakenham, Koo Wee Rup, Beaconsfield Upper, Emerald, Beaconsfield, Lang Lang, Garfield, Cockatoo, Bunyip) is located within walking distance (1200m, or 15 minutes of walk) to nearest health care facilities. Local communities residing in a very large proportion of the study area have to drive to each their nearest health care facilities. Number of MBs and associated population resided within specified walking distances to nearest health care facilities are summarized in Table 5-15 and Table 5-16. It can be seen that in average there are about 24% of the MBs or about 23% of the total population are located within 15min of walking distance to nearest health care facilities, and over 75% of the MBs or over 75% of the total population are located beyond tolerable walking distance to nearest health care facilities.

Table 5-15 Number of MBs within specified travel (walking) time (minutes)

Types	**MBs within specified travel (walking) time (minutes)**			
	5	**10**	**15**	**> 15**
Pharmacy	44	79	76	438
GP/Surgeons clinics	32	57	62	486
Dentists	26	43	43	525

Table 5-16 Number of populaiton within specified travel (walking) time (minutes)

Types	**MBs within specified travel (walking) time (minutes)**			
	5	**10**	**15**	**> 15**
Pharmacy	2,765	5,673	5,615	31,499
GP/Surgeons clinics	1,594	3,748	4,630	35,581
Dentists	1,169	2,645	3,053	38,687

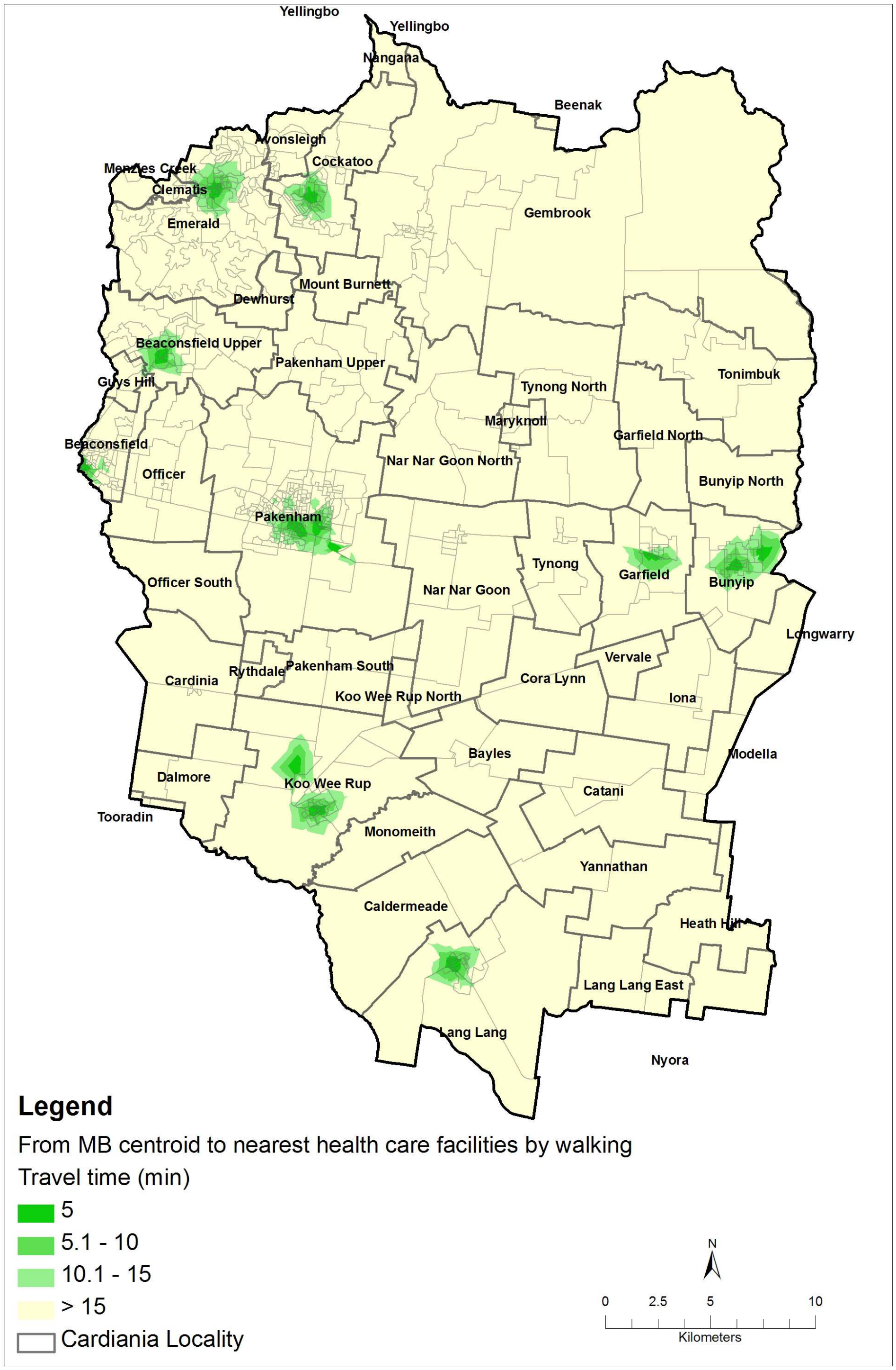


Figure 5-14 Spatial extents of travel (walking) time within or beyond 15 minutes from MB centroids to nearest health care facilities

Figure 5-15, Figure 5-16 and Figure 5-17 show the spatial distributions of MBs (and associated localities) with travel (driving) time to nearest healthcare facilities that are within or beyond mean travel (driving) time (which are listed in Table 5-12), and Table 5-17 and Table 5-18 summarize the corresponding numbers and cumulative percentages of MBs and population. It should also be noted that within the limited extent of the area below mean travel (driving) time, it contains in average over half (60.6% or 386 MBs) of the total MBs (637 MBs) and over half (58.4% or 26622 persons) of the total population (45552 persons).

Table 5-17 Number and percentages of MBs located within or beyond mean travel (driving) time from nearest health care facilities

Health care facilities	<Mean	%	>Mean	%
Pharmacy	442	69.39	195	30.61
GP/Surgeons clinics	337	52.90	300	47.10
Dentists	380	59.65	257	40.35

Table 5-18 Number and percentages of total population located within or beyond mean travel (driving) time from nearest health care facilities

Health care facilities	<Mean	%	>Mean	%
Pharmacy	31,259	68.62	14,293	31.38
GP/Surgeons clinics	23,918	52.51	21,634	47.49
Dentists	24,689	54.20	20,863	45.80

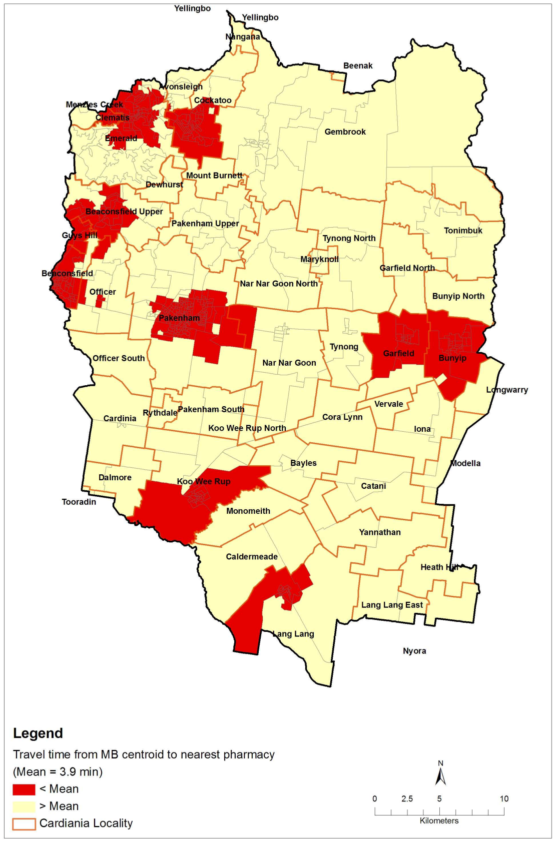


Figure 5-15 Extents of localities within or beyond mean travel (driving) time (= 3.9min) from MB centroids to nearest pharmacies

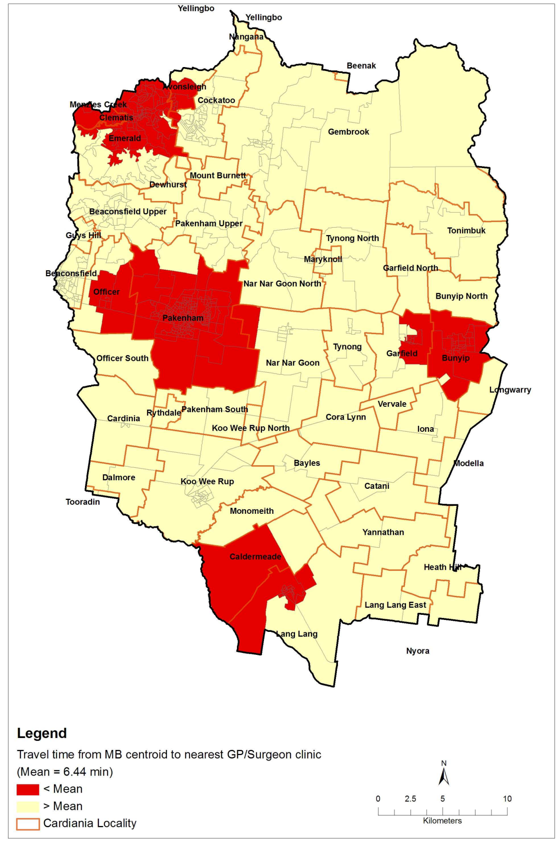


Figure 5-16 Extents of localities within or beyond mean travel (driving) time (= 6.4min) from MB centroids to nearest GP/Surgeons clinics

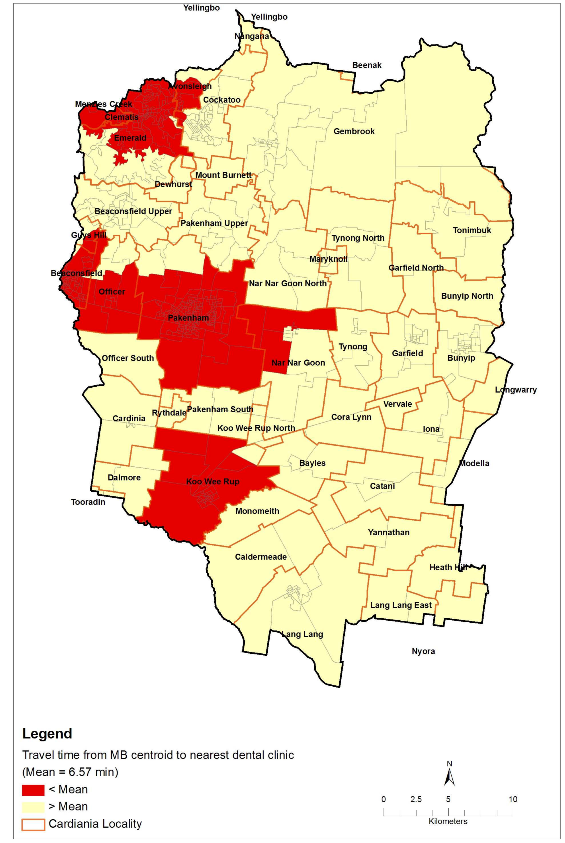


Figure 5-17 Extents of localities within or beyond mean travel time (= 6.6min) from MB centroids to nearest dental clinics

Percentages of the dependent population, low income dwellings, and dwellings with <2 cars that are residing within MBs within or beyond mean travel (driving) time (see Table 5-12) to nearest heath care facilities are summarized in Table 5-19. Similarly, it can be seen that in average although large proportions of the dependent population (62%), low income dwelling (68%), and dwellings with less than 2 cars (69%) are residing in MBs within mean travel (driving) time to closest health care facilities, there are still significant proportions of the dependent population (38%), low income dwelling (32%), and dwellings with less than 2 cars (31%) are residing in MBs with relatively poor spatial accessibility (or beyond mean driving time) to closest health care facilities.

Table 5-19 Percentages of dependent population, low income dwelling and dwelling with < 2 cars located within or beyond mean travel (driving) time to nearest heath care facilities

	% of dependant population			**% of low income dwelling**			**% of dwelling with <2 car**		
	Below mean	**Above mean**	**Total**	**Below mean**	**Above mean**	**Total**	**Below mean**	**Above mean**	**Total**
Pharmacy	22.3	8.7	31.1	8.8	2.6	11.4	18.1	4.7	22.9
GP/Surgeons clinics	17.4	13.7	31.1	7.2	4.2	11.4	14.3	8.6	22.9
Dentists	17.8	13.3	31.1	7.2	4.2	11.4	15.1	7.8	22.9

Figure 5-18, Figure 5-19 and Figure 5-20 show the spatial extents of localities with travel (driving) time within or beyond 10min to nearest pharmacies, GP/Surgeons clinics and dental clinics respectively. Table 5-20 summarizes number of MBs (based on Table 5-12) and Table 5-21 summarizes percentages of the population that located within or beyond 10min of travel (driving) time from their nearest health care facilities. Similarly, it can be seen that over 28% of the population (nearly 13,000 persons) have to drive more than 10min to reach their closest

GP/Surgeons clinic or dental clinic and over 10% of the population (nearly 5,000 persons) need to drive more than 10min to visit their nearest pharmacy.

Table 5-20 Estimated number of MBs below and above 10 minuites of travel time by car from health care facilities

Health care facilities	<10	%	>10	%
Pharmacy	578	90.74	59	9.26
GP/Surgeons clinics	480	75.35	157	24.65
Dentists	475	74.57	162	25.43

Table 5-21 Estimated total population below and above 10 minuites of travel time by car from care facilities

Health care facilities	<10	%	>10	%
Pharmacy	40,686	89.32	4,866	10.68
GP/Surgeons clinics	33,442	73.41	12,110	26.59
Dentists	32,049	70.36	13,503	29.64

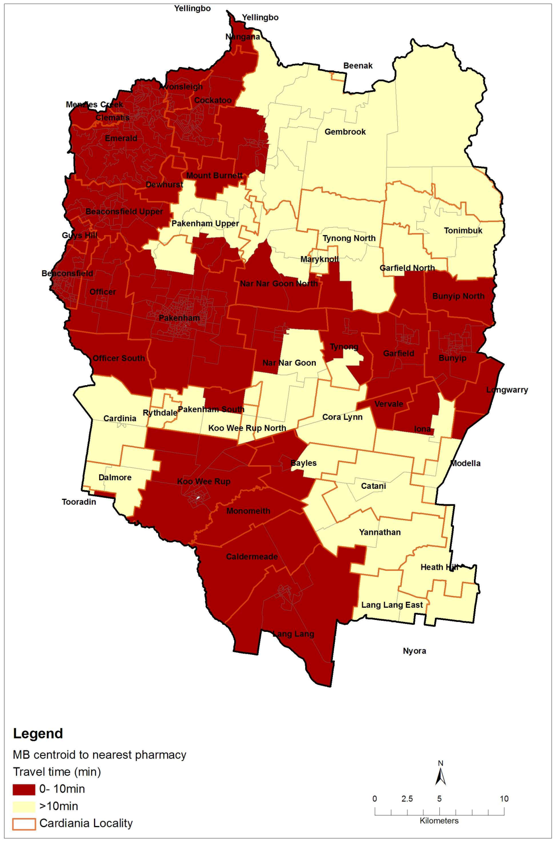


Figure 5-18 Spatial extents of localities within or beyond 10 minutes of travel (driving) time from MB centroids to nearest pharmacies

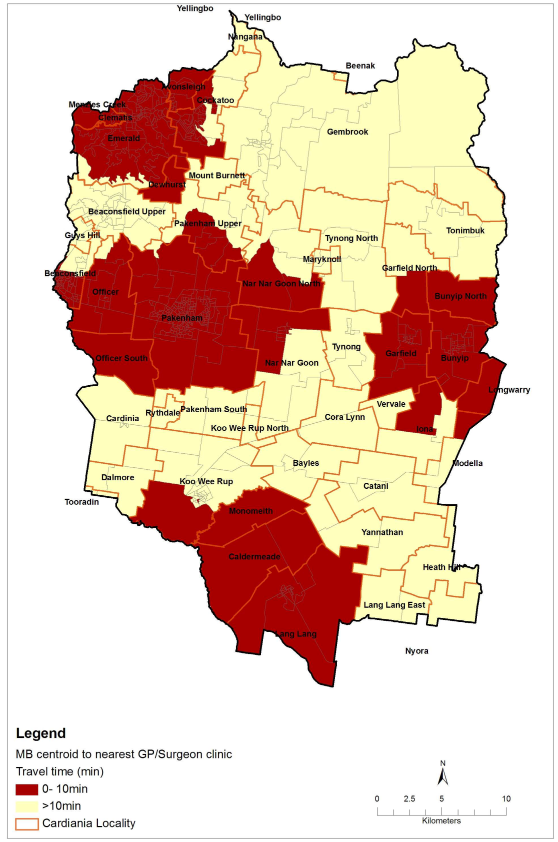


Figure 5-19 Spatial extents of localities within or beyond 10 minutes of travel (driving) time from MB centroids to nearest GP/Surgeons clinics

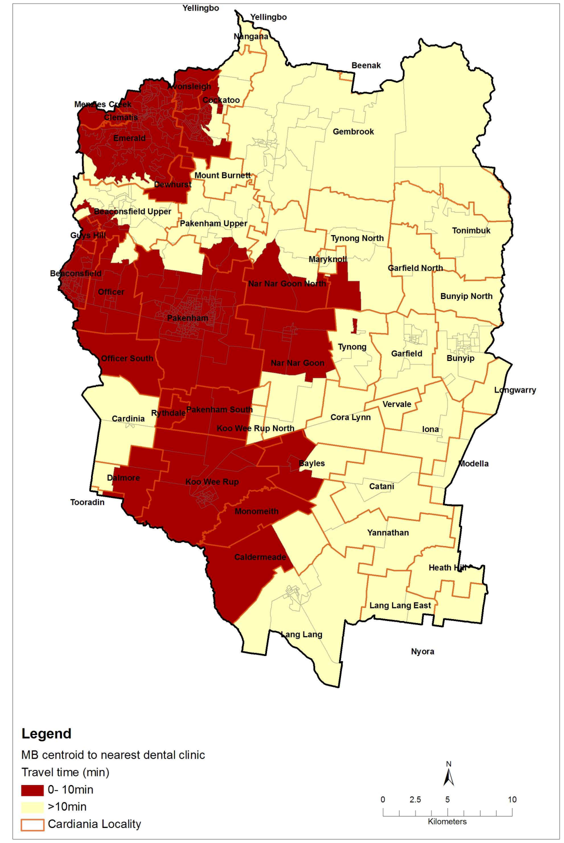


Figure 5-20 Spatial extents of localities within or beyond 10 minutes of travel (driving) time from MB centroids to nearest dental clinics

Percentages of dependent population, low income dwellings and dwellings with less than 2 cars located within or beyond 10min of travel (driving) time to nearest heath care facilities are summarized in Table 5-22. It can be seen that in average very large proportions of the dependent population (79%), low income dwelling (81%), and dwellings with less than 2 cars (84%) are residing in MBs within 10min travel (driving) time to closest health care facilities, and there are also certain proportions of the dependent population (21%), low income dwelling (19%), and dwellings with less than 2 cars (16%) are residing in MBs with relatively poor spatial accessibility (or beyond 10min driving time) to closest health care facilities. It should be noted that persons belong to the dependent population, low income dwellings or dwellings with < 2 cars may not have a car or may not be able to drive a car to get to their nearest health care facilities when needed.

Table 5-22 Percentages of dependent population, low income dwellings and dwellings with <2 cars within or beyond 10min of travel (driving) time to nearest heathcare facilities

	% of dependant population			% of low income dwelling			% of dwelling with <2 car		
	Below 10min	Above 10min	Total	Below 10min	Above 10min	Total	Below 10min	Above 10min	Total
Pharmacy	28.2	2.9	31.1	10.5	0.8	11.4	21.5	1.4	22.9
GP/Surgeons clinics	23.2	7.8	31.1	9.0	2.4	11.4	18.2	4.6	22.3
Dentists	22.3	8.8	31.1	8.4	2.9	11.4	17.7	5.1	22.9

Figure 5-21 shows the statistical relationships between travel distance and travel (driving) time from MB centroids to nearest Pharmacies, GP/Surgeons clinics and dental clinics. As expected, in general, there exists a stronger positive linier relationship between shorter travel distance and travel (driving) time, and a weaker positive linier relationship for longer travel distance or driving time. The possible explanation for the weaker correlation between longer travel distance and travel time may be that as the longer the travel takes, the more different road conditions and may be encountered, resulting in more varied travel time to reach their nearest health care facilities.

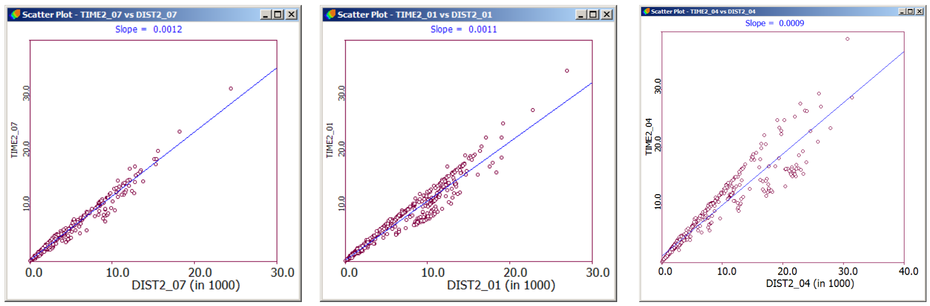


Figure 5-21 Relationships (indicated by Moran's I scatterplot) between travel distance and travel (driving) time from MB centroids to nearest Pharmacies (left), GP/Surgeons clinics (middle), and dental clinics (right)

5.2.3 Spatial accessibility index

According to the procedures described in Section 3.7.2, the index value of spatial accessibility to health care facilities for each MB centroid has been derived in three steps: first, the travel distances from MB centroids to nearest pharmacies, GP/Surgeon clinics and dental clinics are normalized; then, the weights for normalized travel distances to nearest pharmacies, GP/Surgeon clinics and dental clinics are determined (= 0.5, 0.4, and 0.1, respectively, see Section 3.7.3 for details); and finally, the index values for spatial accessibility to health care facilities are calculated for each MB centroid.

Table 5-23 summarizes statistics for the normalized travel distances for pharmacies, GP/Surgeon clinics, and for the spatial accessibility index values. Figure 5-22, Figure 5-23, Figure 5-24 and Figure 5-25 show the spatial distributions of the normalized travel distances and the spatial accessibility index values respectively. It is clear that in Cardinia Shire there exists an obvious spatial variation in travel distances to health care facilities. As indicated in the maps by dark navy blue colour, normalized travel distances are very small in the localities of Pakenham, Beaconsfield and Emerald. Similar spatial distribution is shown for the spatial accessibility index values in Figure 5-25, where these three localities plus additional localities like Bunyip, Koo Wee Rup and Lang Lang all have low spatial accessibility index values. Localities in the north eastern part of the study areas have very high index values of spatial accessibility to health care facilities, due to the absence of health care facilities.

Table 5-23 Summary statistics for normalised travel distances to nearest pharmacy, GP/Surgeon clinics, dental clinics, and spatial accessibilty index values (SAIV)

Summary statistics	Pharmacies	GP/Surgeons clinics	Dentists	SAIV
Minimum	0	0	0	0.0014
Maximum	1	1	1	0.9978
Mean	0.1314	0.2159	0.1965	0.1717
SD	0. 136773	0.1801	0.1998	0.1366

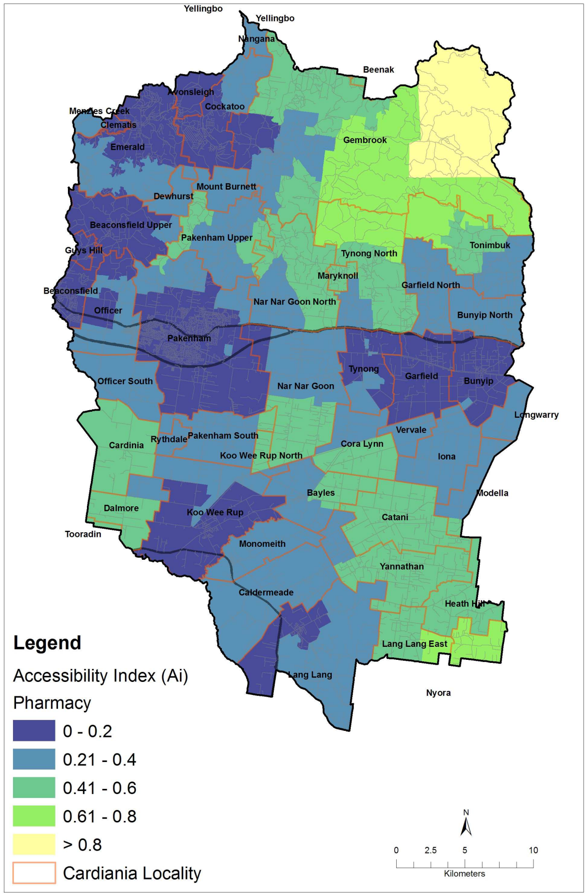


Figure 5-22 Spatial distribution of normalized travel distances to nearest pharmacy

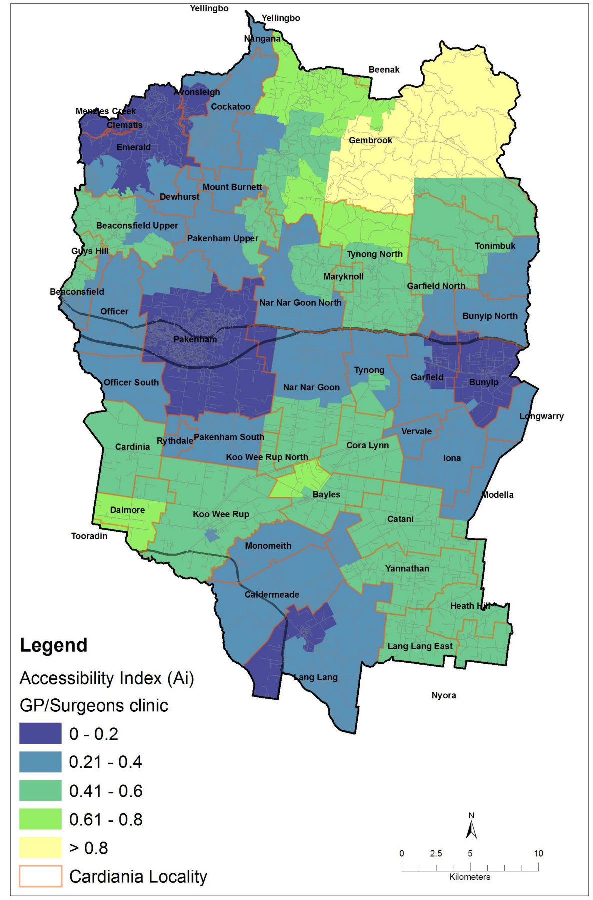


Figure 5-23 Spatial distribution of normalized travel distances to nearest GP/Surgeons clinics

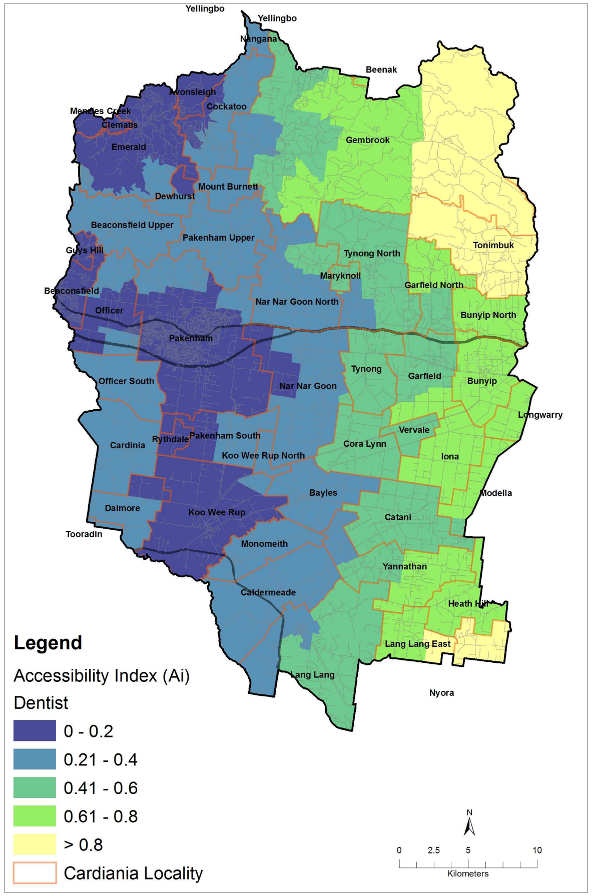


Figure 5-24 Spatial distribution of normalized travel distances to nearest dental clinics.

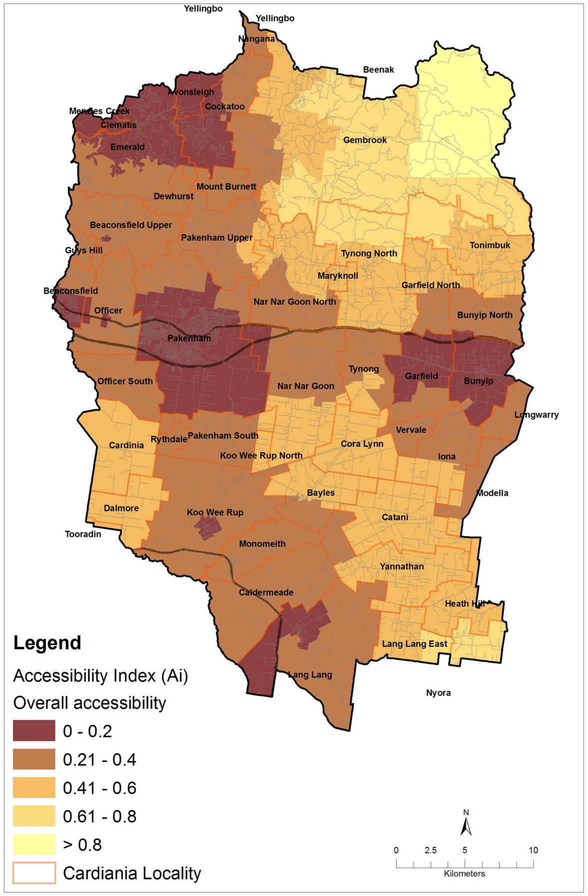


Figure 5-25 Spatial distribution of index values for spatial accessibility to health care facilities

As shown in Table 5-24 and Table 5-25 and in Figure 5-26 and Figure 5-27, large proportions of MBs (66.5% or 423 MBs) and total population (64.1% or 29,206 persons) are located within the specified interval of 0-0.2 for both normalized travel distances to health care facilities and spatial accessibilty index values (SAIVs).

Table 5-24 Number of MBs within specified normalised travel distances or SAIVs

	Normalized travel distances or SAIVs					
Number of MBs	**0- 0.2**	**0.2- 0.4**	**0.4- 0.6**	**0.6- 0.8**	**0.8-1.0**	**Total**
Pharmacy	504	91	36	5	1	637
GP/Surgeons clinic	336	173	117	9	2	637
Dental clinic	401	140	52	38	6	637
SAIV	**453**	**131**	**45**	**7**	**1**	**637**

Table 5-25 Number of persons within specified normalised travel distances or SAIVs

	Normalized travel distances or SAIVs					
Number of persons	**0- 0.2**	**0.2- 0.4**	**0.4- 0.6**	**0.6- 0.8**	**0.8-1.0**	**Total**
Pharmacy	35,211	6,865	3,395	56	25	45,552
GP/Surgeons clinic	23,788	12,053	9,132	554	25	45,552
Dental clinic	26,180	11,413	4,845	2,958	156	45,552
SAIV	**31,645**	**9,542**	**4,120**	**220**	**25**	**45,552**

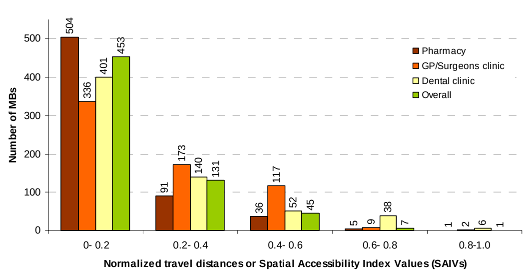


Figure 5-26 Number of MBs within specified normalized travel distances or SAIVs

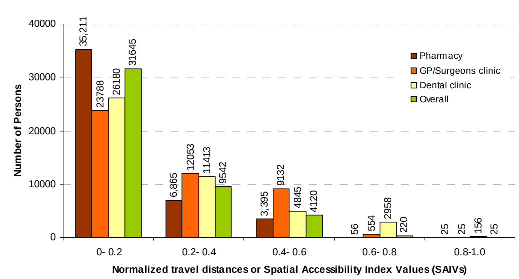


Figure 5-27 Number of persons within specified normalized travel distances or SAIVs

Spatial extents of localities within or beyond mean accessibility index value (=0.1717) are shown in. It is clear that only a small proportion of the study areas and a few localities have very high spatial accessibility (indicated by very low spatial accessibility index values) to nearest health care facilities, but a large proportion of population reside in locations with high spatial accessibility to health care facilities due to clustered distribution population within the study area.

Table 5-26 shows that large proportions of the dependent population (65%), low income dwellings (73%), and dwellings with less than 2 cars (73%) resided in locations within mean accessibility index value, and significant proportions of residents in dependent population (35%), low income dwellings (27%), and dwellings with less than 2 cars (27%) resided in locations with poor spatial accessibility to health care facilities.

Table 5-26 Percentages of dependent population, low income dwellings and dwellings with <2 cars below and above mean spatial accessibility index value

	% of dependant population			% of low income dwelling			% of dwelling with <2 car		
	Below Mean	**Above Mean**	**Total**	**Below Mean**	**Above Mean**	**Total**	**Below Mean**	**Above Mean**	**Total**
SAIV	20.2	10.9	31.2	8.3	3.2	11.4	16.7	6.2	22.9

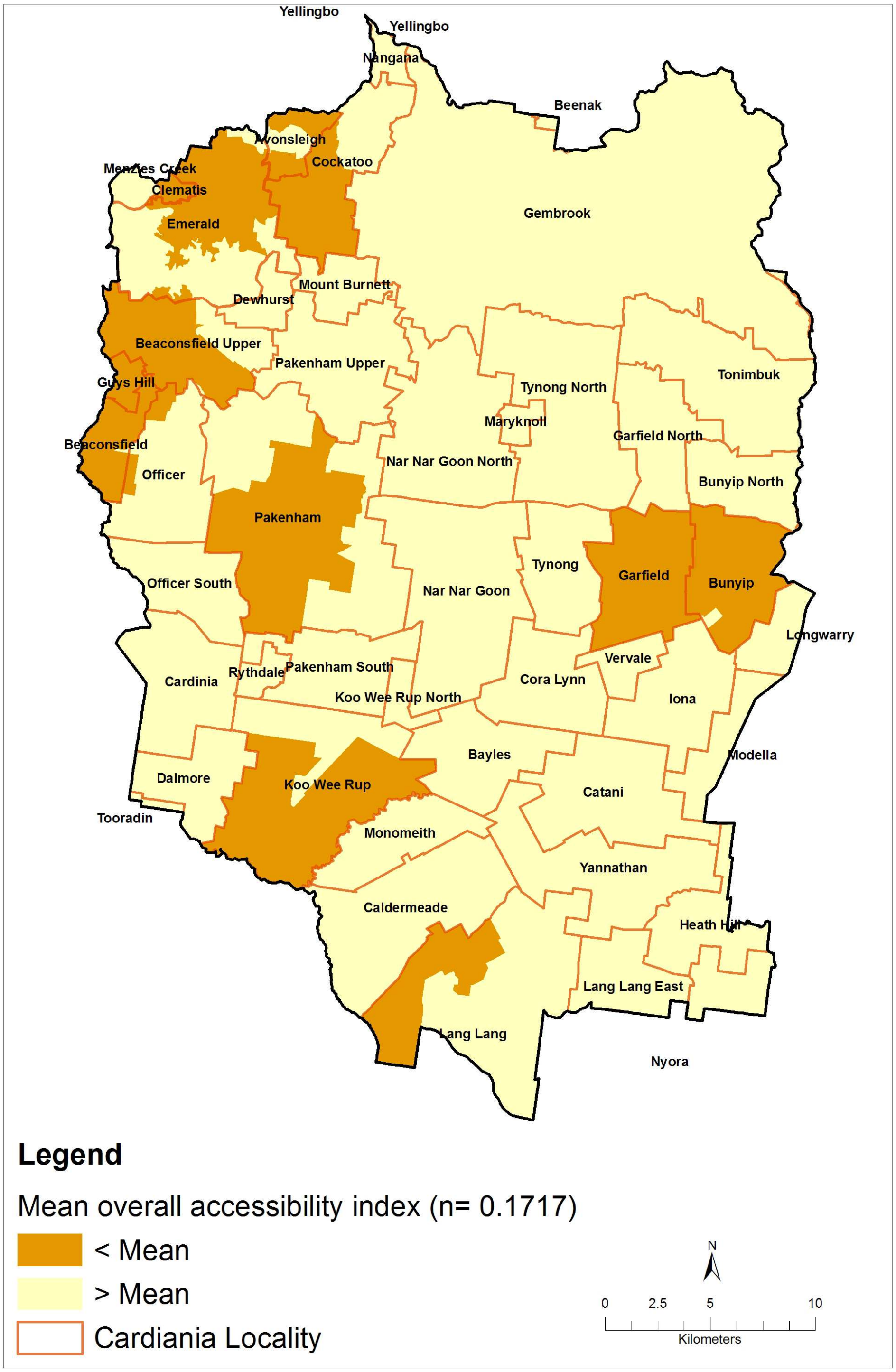


Figure 5-28 Spatial extents of localities within or beyond mean index value of spatial accessibility to nearest health care facilities

5.3 Mapping spatial clusters

According to procedures discussed in Section 3.7.3, spatial clusters of MBs are mapped using MB-level spatial accessibility index values and MB-level population counts as weights.

First, spatial extents of statistically significant hot spots (spatial clusters of high values within a specific geographic area) and cold spots (spatial clusters of low values within a specific geographic area) are identified with the Getis-Ord Gi* statistic (based on the Z-score) for MB-level spatial accessibility index values and population counts, as shown in Figure 5-29 and Figure 5-30, respectively. Table 5-27 shows the number and percentages of MBs and population within hot spots, cold spots and no clustering areas identified using Getis-Ord Gi* statistic and MB-level spatial accessibility index values. Approximately 20% of MBs (over 10,000 persons) were identified within hot spots (low spatial accessibility), over 40% of MBs (with more than 19,000 persons) were identified within cold spots (high accessibility), and over 40% of MBs (with more than 16,000 persons) were identified within no clustering or random distribution areas. Table 5-28 shows the number and percentages of MBs and population within hot spots, cold spots and no clustering areas identified using Getis-Ord Gi* statistic and MB-level population counts. Over 17% of MBs (with more than 12,000 persons) are identified within hot spots (high concentration of MB-level population counts) in the localities of Cokatoo, Mount Burnett, Pakenham upper, Tynong North, Maryknoll, Garfield, Bunyip, Cora Lynn and Vervale; about 17% shows (with less than 3,000 persons) are identified within cold spots (low concentration of MB-level population counts) in the localities of Officer, Officer South, Beaconsfield, Cardinia, Rythdale, Pakenham south and some part of

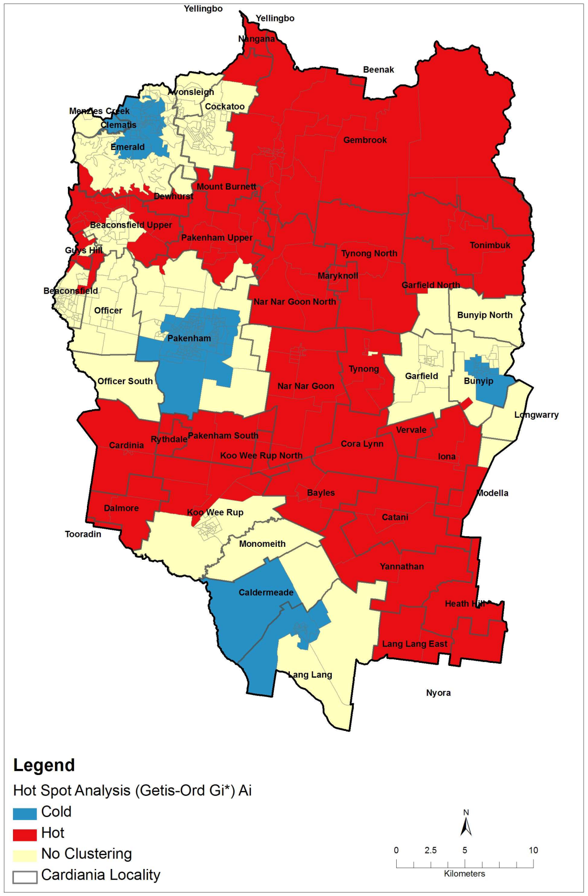
Tonimbuk, Gembrook and Pakenham; and over 66% of MBs (with a bit over 30,000 persons) are identified within no clustering or random distribution areas.

Table 5-27 Number and percentages of MBs and population within hot spots, cold spots and no clustering areas identified using Getis-Ord Gi* statistic and MB-level spatial accessbility index values

Cluster types	MB	%	Population	%
Hot	122	19.15	10,133	22.24
Cold	260	40.82	19,191	42.13
No Clustering	255	40.03	16,228	35.63
Total	**637**	**100**	**45,552**	**100**

Table 5-28 Number and percentages of MBs and population within hot spots, cold spots and no clustering areas identified using Getis-Ord Gi* statistic and MB-level population counts

Cluster types	MB	%	Population	%
Hot	108	17.0	12,357	27.1
Cold	107	16.8	2,872	6.3
No Clustering	422	66.2	30,323	66.6
Total	**637**	**100**	**45,552**	**100**



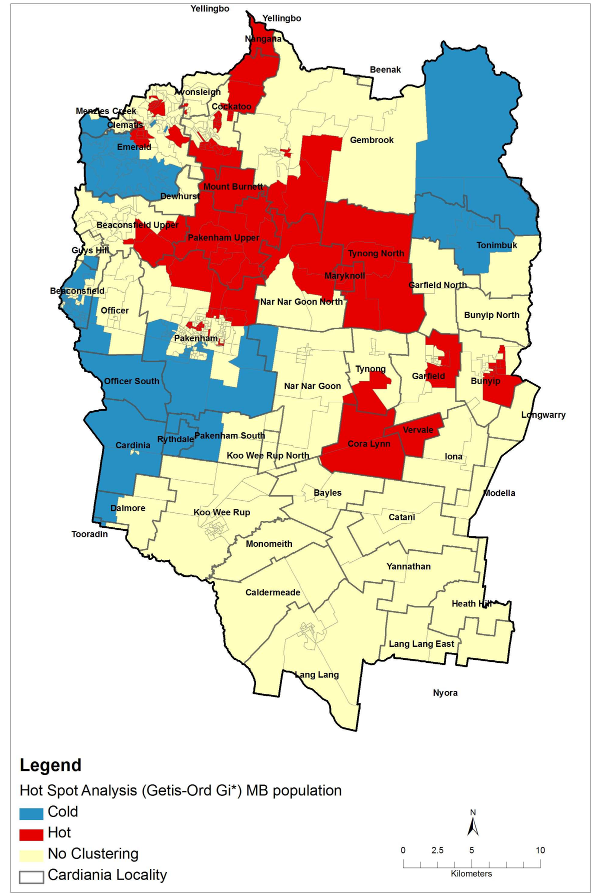


Figure 5-29 Spatial extents of hot spots, cold spots and no clustering areas of MB-level spatial accessibility index values identified using Getis-Ord Gi* statistic

Figure 5-30 Spatial extents of hot spots, cold spots and no clustering areas of MB-level population counts identified using Getis-Ord Gi* statistic

Then, spatial extents of statistically significant spatial clusters of HH, LL, LH, and HL are identified with the Anselin Local Moran's I statistic (based on the COType and LMiPValue) for MB-level spatial accessibility index values and population counts, as shown in Figure 5-31 and Figure 5-32, respectively. Table 5-29 summarizes the number and percentages of MBs and population within HH, LL, LH, and HL spatial clusters and within no clustering areas identified with the Anselin Local Moran's I statistic (based on the COType and LMiPValue) for MB-level spatial accessibility index values and MB-level spatial accessibility index values. It shows that over 20% of the MBs and total population are identified within LL spatial clusters (that have high spatial accessibility), over 15% the MBs and total population are identified within HH spatial clusters (that have low spatial accessibility), and over 60% of the MBs and total population are identified within no clustering areas. Table 5-30 summarizes the number and percentages of MBs and population within HH, LL, LH, and HL spatial clusters and within no clustering areas identified with the Anselin Local Moran's I statistic (based on the COType and LMiPValue) for MB-level population counts. It shows that over 80% of the MBs and total population are identified within no clustering areas, and only a little over 16% of the MBs and total population are identified within spatially clustered areas.

Table 5-29 Number and percentages of MB and population within HH, LL, LH and HL clusters and no clustering areas identified using Anselin Local Moran's I statistic and MB-level spatial accessbility index values

Cluster types	MB	%	Population	%
HH	97	15.23	8232	18.07
LL	135	21.19	9551	20.97
LH	0	0	0	0
HL	0	0	0	0
No Clustering	405	63.58	27769	60.96
Total	**637**	**100**	**45552**	**100**

Table 5-30 Number and percentages of MB and population within HH, LL, LH and HL clusters and no clustering areas identified using Anselin Local Moran's I statistic and MB-level populaiton counts

Cluster types	MB	%	Population	%
HH	39	6.1	5,957	13.1
LL	63	9.9	575	1.3
LH	14	2.2	22	0.0
HL	6	0.9	842	1.8
No Clustering	515	80.8	38,156	83.8
Total	**637**	**100**	**45552**	**100**

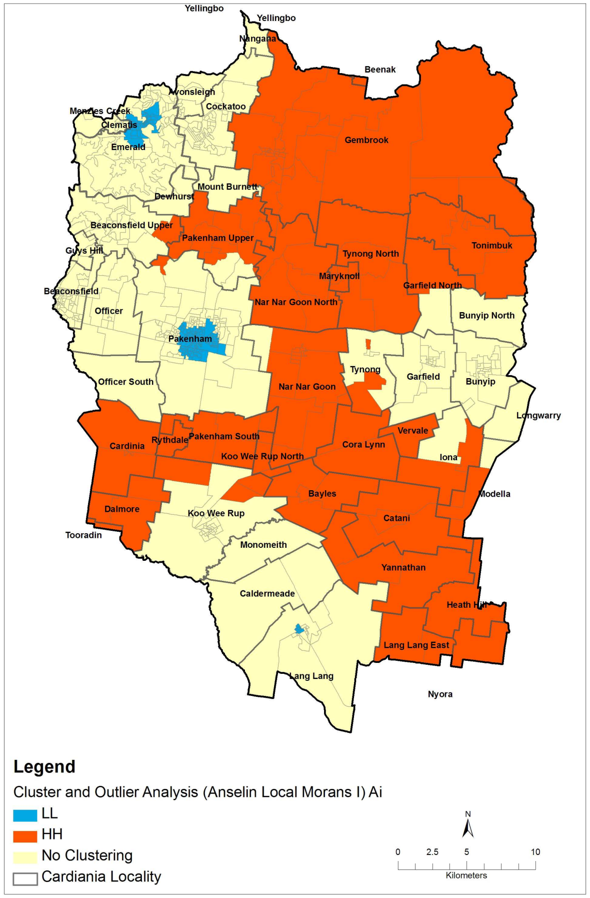


Figure 5-31 Spatial extents of statistically significant HH and LL spatial clusters and no clustering areas of SAIVs

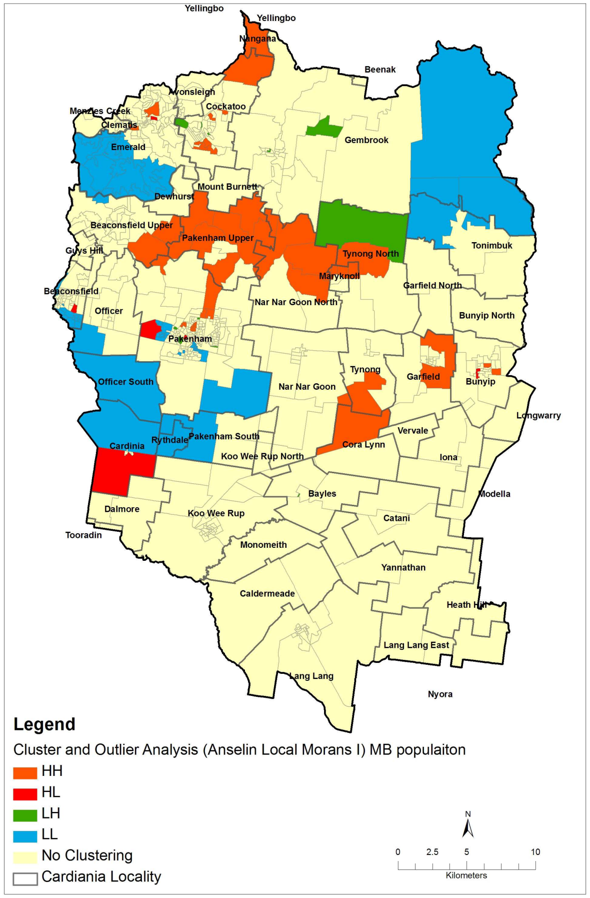


Figure 5-32 Spatial extents of statistically significant HH and LL spatial clusters and no clustering areas of population counts

Finally, spatial extents of statistically significant spatial clusters of HH, LL, LH, and HL are identified with the univariate local indicators of spatial association (LISA) analysis (based on 95% statistical significance of COType) for MB-level spatial accessibility index values and population counts, as shown in Figure 5-33 and Figure 5-34 respectively.

Number and percentages of MBs and population within HH, LL, LH, and HL spatial clusters and no clustering areas identified with univariate LISA analysis on MB-level SAIVs and MB-level population counts are summarized in Table 5-31 and Table 5-32. For MB-level spatial accessibility, about 17% of the MBs (with more than 9,000 persons) re identified within the HH spatial clusters (which have low spatial accessibility to health care facilities), about 41% of the MBs (with more than 19,000 persons) are identified within the LL spatial clusters (which have high spatial accessibility to health care facilities), and over 41% of the MBs (with more than 16,000 persons) are identified within no clustering areas. For MB-level population counts, about 12% of the MBs (with more than 8,000 persons) are identified within the HH spatial clusters (which have low spatial accessibility to health care facilities), about 14% of the MBs (with more than 2,000 persons) are identified within the LL spatial clusters (which have high spatial accessibility to health care facilities), and over 69% of the MBs (with more than 32,000 persons) are identified within no clustering areas.

Table 5-31 Number and percentages of MBs and population within HH, LL, LH, and HL spatial clusters and no clustering areas (univariate LISA of MB-level SAIVs)

Cluster types	MB	%	Population	%
HH	108	16.9	9,009	19.7
LL	261	40.9	19,336	42.4
LH	0	0	0	0
HL	4	0.6	321	0.70
No Clustering	264	41.4	16,886	37.0
Total	**637**	**100**	**45,552**	**100**

Table 5-32 Number and percentages of MBs and population within HH, LL, LH, and HL spatial clusters and no clustering areas (univariate LISA of MB-level population counts)

Cluster types	MB	%	Population	%
HH	75	11.8	8,860	19.5
LL	87	13.7	2,009	4.4
LH	25	3.9	1,002	2.2
HL	19	1.6	999	2.2
No Clustering	440	69.1	32,682	71.7
Total	**637**	**100**	**45,552**	**100**

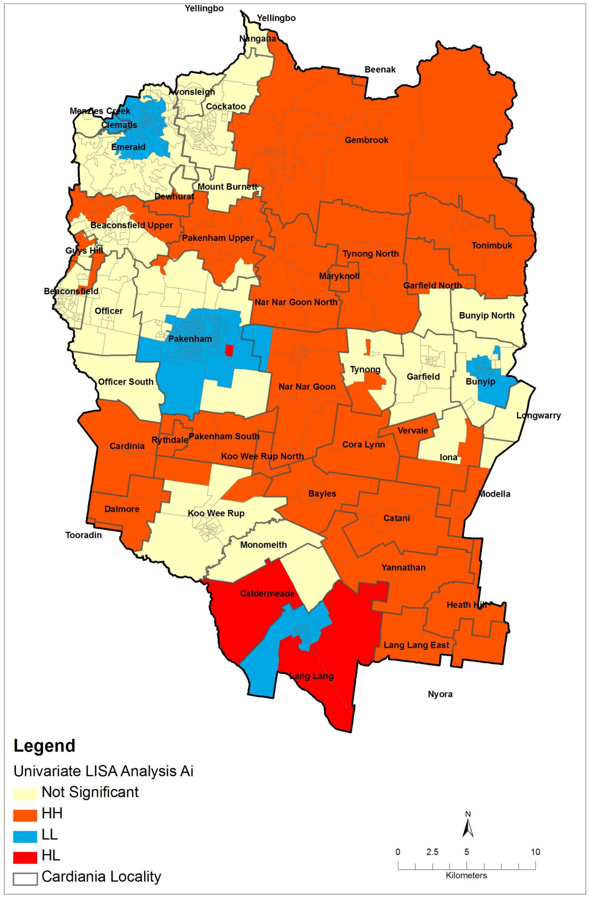


Figure 5-33 Univariate LISA analysis using MB-level spatial accessibility index values

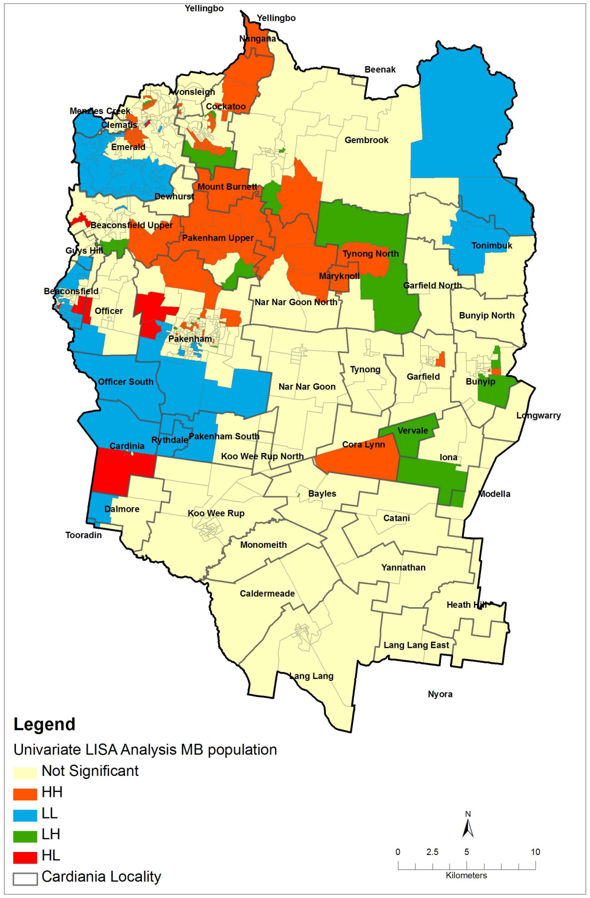


Figure 5-34 Univariate LISA analysis using MB-level population counts

5.4 Identifying disadvantaged locations / local communities

According to procedures discussed in Section 3.7.4, disadvantaged locations or local communities are identified in this study by overlaying (intersection or union) spatial clusters of high demands (indicated by hot spots or HH spatial clusters of MB-level population counts) and spatial clusters of low accessibility to health care facilities (indicated by hot spots or HH spatial clusters of MB-level spatial accessibility to health care facilities).

Spatial extents of disadvantaged locations / local communities resulting from union-based spatial overly analysis of the two types of hot spots (MB-level SAIVs and MB-level population counts) identified with the Getis-Ord Gi* statistic are shown in Figure 5-35: the Cold-Cold spatial clusters indicate spatial coincidents of cold spots of MB-level SAIVs with cold spots of MB-level population counts, identified by the Getis-Ord Gi* statistic; the Hot-Hot spatial clusters indicate spatial coincidents of hot spots of MB-level SAIVs with hot spots of MB-level population counts, identified by the Getis-Ord Gi* statistic; and all other cases are labeled as No Cluster in the map. Table 5-33 summarizes the number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the Gi* statistic: about 9% of the total population or nearly 4,000 persons are identified in disadvantaged locations.

Spatial extents of disadvantaged locations / local communities resulting from union-based spatial overly analysis of the two types of HH spatial clusters (MB-level SAIVs and MB-level population counts) identified with the local Moran's I statistic are shown in Figure 5-36: the LL-LL spatial clusters indicate spatial coincidents of LL spatial clusters of MB-level SAIVs with LL spatial clusters of MB-level population counts, identified by the local Moran's I statistic; the HH-HH spatial clusters indicate spatial coincidents of HH spatial clusters of MB-level SAIVs with HH spatial clusters of MB-level population counts, identified by the local Moran's I statistic; and all other cases are labeled as No Cluster in the map. Table 5-34 summarizes the number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the local Moran's I statistic: about 4.5% of the total population or over 2000 persons are identified in disadvantaged locations.

Spatial extents of disadvantaged locations / local communities resulting from union-based spatial overly analysis of the two types of HH spatial clusters (MB-level SAIVs and MB-level population counts) identified with the univariate LISA analysis are shown in Figure 5-37: the LL-LL spatial clusters indicate spatial coincidents of LL spatial clusters of MB-level SAIVs with LL spatial clusters of MB-level population counts, identified with the univariate LISA analysis; the HH-HH spatial clusters indicate spatial coincidents of HH spatial clusters of MB-level SAIVs with HH spatial clusters of MB-level population counts, identified with the univariate LISA analysis; and all other cases are labeled as No Cluster in the map. Table 5-35 summarizes the number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the univariate LISA analysis: about 5.5% of the total population or over 2500 persons are identified in disadvantaged locations

Table 5-33: Number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the Gi* statistic

Cluster types	MB	%	Population	%
Hot spots	32	5.02	3,976	8.73
Cold spots	32	5.02	1,096	2.41
No Clustering	573	89.95	40,480	88.87
Total	**637**	**100**	**45,552**	**100**

Table 5-34 Number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the Local Moran's I statistic

Cluster types	MB	%	Population	%
HH-HH	13	2.04	2,063	4.53
LL-LL	10	1.57	148	0.32
No Clustering	614	96.39	43,341	95.15
Total	**637**	**100**	**45,552**	**100**

Table 5-35 Number and percentages of MBs and population in spatial clusters resulted from the union of spatial clusters identified with the univariate LISA analysis

Cluster types	MB	%	Population	%
HH-HH	18	2.83	2,515	5.52
LL-LL	22	3.45	725	1.59
No Clustering	597	93.72	42,312	92.89
Total	**637**	**100**	**45,552**	**100**

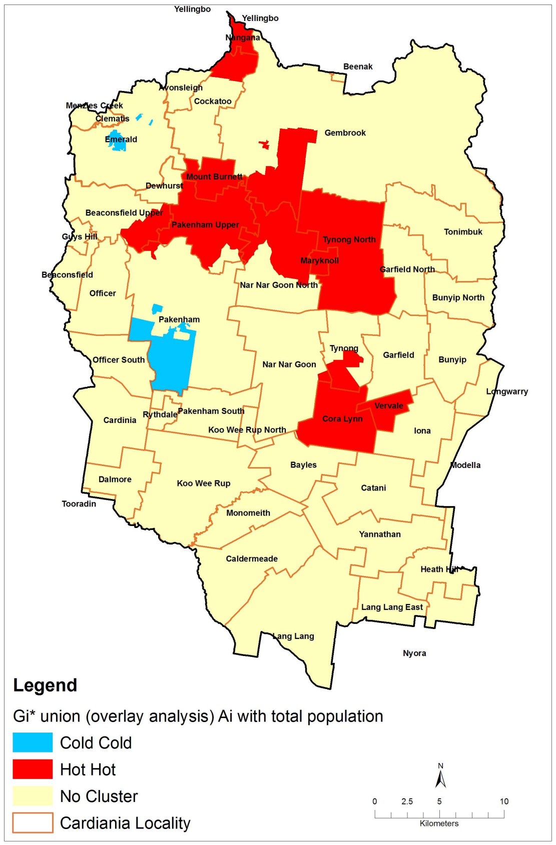


Figure 5-35 Results from union-based overly of spatial clusters identified with the Getis-Ord Gi* statistic

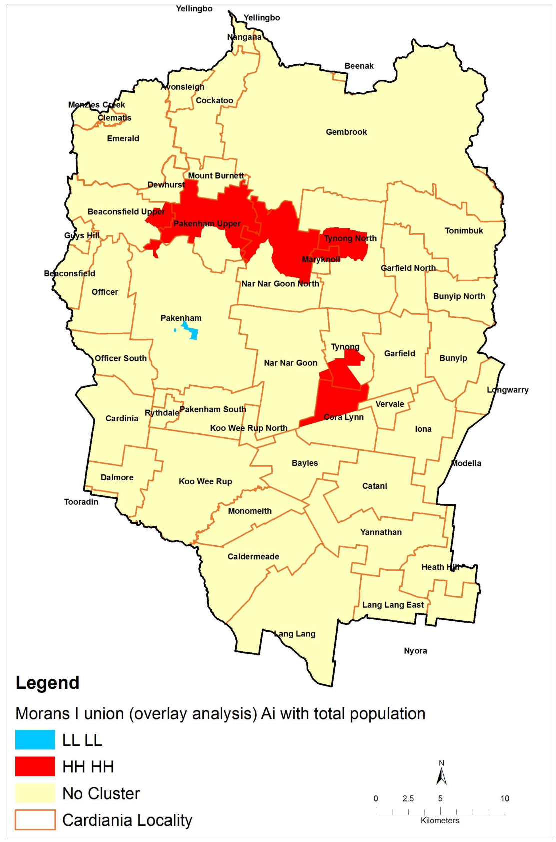


Figure 5-36 Results from union-based overly of spatial clusters identified with the Local Moran's I statistic

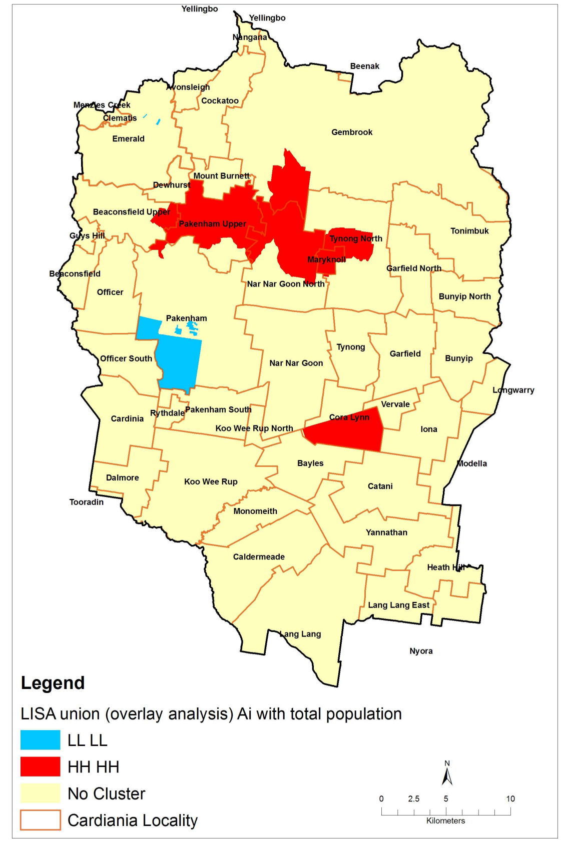


Figure 5-37 Results from union-based overly of spatial clusters identified with the univariate LISA analysis

The three outcomes presented above are different, and it is difficult to decide which one is better. To overcome this difficulty, the three different outcomes are combined to generate two scenarios: (1) a conservative scenario, and (2) a less conservative scenario, according to rules established in Table 5-36. . It should be noted that in Table 5-36, the number 1 refers to Cold-Cold in Figure 5-36, LL-LL in Figure 5-37 and LL-LL in Figure 5-38, and refers to locations with low demand for health care facilities and good spatial accessibility to health care facilities in both scenarios 1 and 2; the number 2 refers to Hot-Hot in Figure 5-36, HH-HH in Figure 5-37 and HH-HH in Figure 5-38, and refers to locations with high demand for health care facilities and poor spatial accessibility to health care facilities in both scenarios 1 and 2; and the number 3 refers to all other cases in the three Figures of 5-36, 5-37 and 5-38 and the two scenarios of 1 and 2.

Table 5-36 Rules for creating scenarios 1 and 2 from the three overlay outcomes

Figure 5-36	Figure 5-37	Figure 5-38	Scenario 1	Scenario 2
1	1	1	1	1
1	1	2	3	1
1	1	3	3	1
1	2	1	3	1
1	2	2	3	2
1	2	3	3	3
1	3	1	3	1
1	3	2	3	3
1	3	3	3	3
2	1	1	3	3
2	1	2	3	2
2	1	3	3	3
2	2	1	3	2
2	2	2	2	2
2	2	3	3	2
2	3	1	3	2
2	3	2	3	2
2	3	3	3	3
3	1	1	3	1
3	1	2	3	3
3	1	3	3	3
3	2	1	3	3
3	2	2	3	1
3	2	3	3	3
3	3	1	3	3
3	3	2	3	3
3	3	3	3	3

Spatial extents of the three types of locations in scenarios 1 and 2 are shown in Figure 5-38 and Figure 5-39, respectively. The number and percentages of MBs and population for each location types for both scenarios are summarized in Table 5-38 and Table 5-37, respectively. According to the conservative scenario, about 2,000 persons are identified in disadvantaged locations (in the localities of Cora Lynn, Pakenham Upper, Maryknoll and Tynong North) with poor spatial accessibility to health care facilities. Based upon the less conservative scenario, more than 2,600 persons are identified in disadvantaged locations (in the localities of Pakenham

Upper, Maryknoll and Tynong North) with poor spatial accessibility to health care facilities.

Table 5-37 Number and percentages of MBs and population for different location types in scenario 1 (conservative)

Location types	MB	%	Population	%
HH-HH (2)	12	1.9	1,914	4.2
LL-LL (1)	9	1.4	146	0.3
No Clustering (3)	616	96.7	43,492	95.6
Total	**637**	**100**	**45,552**	**100**

Table 5-38 Number and percentages of MBs and population for different location types in scenario 2 (less conservative)

Location types	MB	%	Population	%
HH-HH (2)	19	2.9	2,664	5.8
LL-LL (1)	23	3.6	727	1.6
No Clustering (3)	596	93.6	42,310	92.9
Total	**637**	**100**	**45,552**	**100**

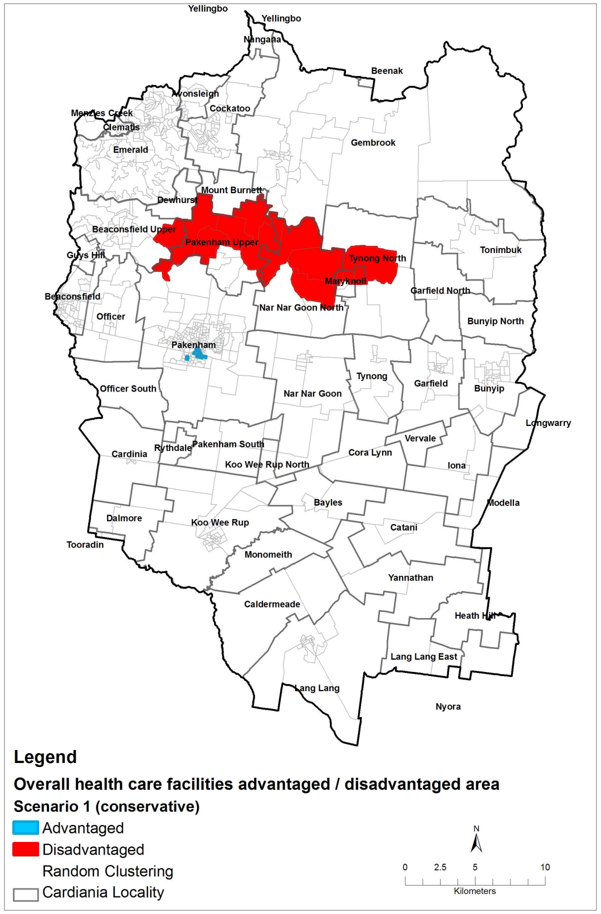


Figure 5-38 Spatial extents of the three location types in scenarios 1

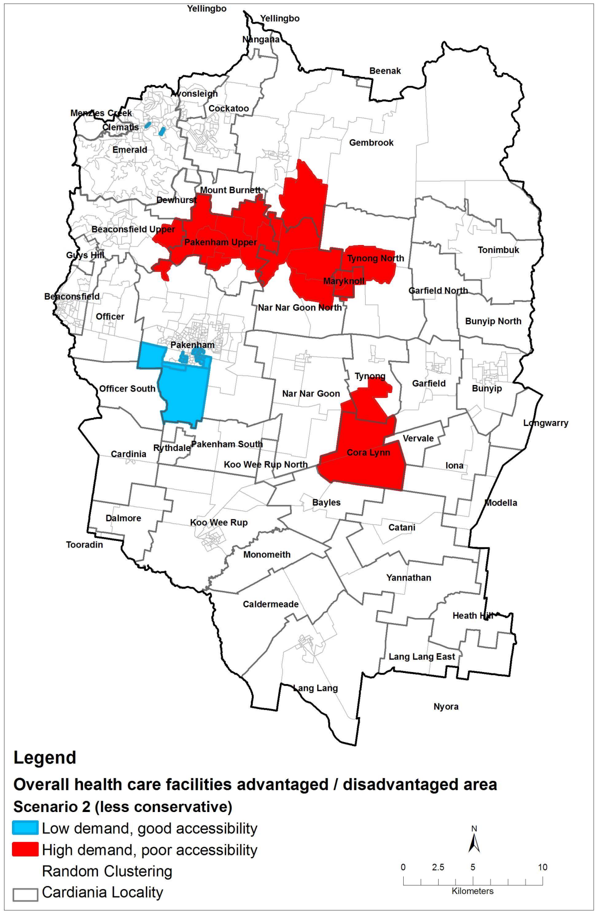


Figure 5-39 Spatial extents of the three location types in scenarios 2

5.5 Conclusion

The investigation of the spatial accessibility to health care facilities in Cardinia Shire has revealed that local residents have to drive over 3km (3228.6m) or 4 minutes for a pharmacy, drive about 6km or over 6 minutes for a GP/Surgeon’s clinic, or a dental clinic, and in average they have to drive for about 5km or about 6 minutes to visit their respective nearest health care facilities. There are 27.5 % (12536 persons), 20.3% (9241 persons), and 12.9% (5867 persons) of the population reside within a tolerable walking distance of 1.2km from the nearest pharmacies, GP/Surgeons clinics and dental clinic respectively, and majority of the population have to drive or use public transportation to reach their nearest health care facilities. In average there are about 23% of the total population are located within 15min of walking distance to nearest health care facilities, and over 75% of the total population are located beyond tolerable walking distance to nearest health care facilities. In the Shire, significant proportions of residents in dependent population (35%), low income dwellings (27%), and dwellings with less than 2 cars (27%) resided in locations with poor spatial accessibility to health care facilities.

Based upon spatial clustering analysis, there are about 9% of the total population or nearly 4,000 persons are identified with the Gi* statistic living in disadvantaged locations; about 4.5% of the total population or over 2000 persons are identified with the local Moran’s I statistic living in disadvantaged locations; and about 5.5% of the total population or over 2500 persons are identified with the univariate LISA analysis living in disadvantaged locations.

According to the conservative scenario, about 2,000 persons are identified in disadvantaged locations (in the localities of Cora Lynn, Pakenham Upper, Maryknoll and Tynong North) with poor spatial accessibility to health care facilities; and based upon the less conservative scenario, more than 2,600 persons are identified in disadvantaged locations (in the localities of Pakenham Upper, Maryknoll and Tynong North) with poor spatial accessibility to health care facilities.

Chapter 6 Discussion and Conclusion

6.1 Introduction

This study has sought to investigate spatial accessibility to health care facilities by local residents of the Cardinia Shire. The primary objective of the study was to examine spatial variation in access to health care facilities in terms of spatial distributions of the health care facilities within the Shire, the potential users of those health care facilities and the positioning of the transportation infrastructure. To accomplish the research objectives (described in chapter 1) relevant spatial and tabular datasets were collected from appropriate sources (e.g. Australian Bureau of Statistics, Yellow pages, Department of Human Services, VicMap etc). A GIS based spatial analysis method has been developed to refine census attributes into Mesh Blocks (MB); to map spatial distributions of population, health care facilities and transportation system; and to identify disadvantaged locations / local communities by means of spatial clustering and overlaying analysis. Refining the census dataset into higher spatial resolution permitted the analysis to reveal the spatial variation of the data in details. This chapter is designed to provide an overview of the main research findings described in chapters 4 and 5, including the summarized characteristics of the population; health care facilities, transportation infrastructure, the GIS based investigation of spatial accessibility to health care facilities, and the identification of disadvantaged locations.

6.2 Demographic characteristics and spatial variations

Approximately 46,000 people reside within Cardinia Shire. The number of persons identified in each MBs varies between 0 and 242. The population density varies between 0 and 11,583 persons / km^2 with mean value of 768 persons / km^2. Demographic analysis as identified the following population variables for this study: number of total dependent population, dwellings with low income and dwellings with less than 2 cars. Spatial clustering analysis methods including Getis Gi* statistics, Anselin Local Moran's I and Univariate LISA analysis are deployed to reveal spatial clusters of MB-level population counts and MB-level spatial accessibility index values at local scale. Results from the analysis confirmed that in Cardinia Shire population distribution was clustered into large townships and only a small proportion of the population in Cardinia Shire resided within walking distance from health care facilities.

6.3 Transportation characteristics and spatial variations

Transportation infrastructures were characterized in order to understand the overall transportation system in the study area. The study shows that the distribution of the transportation infrastructure also varied across the study area. In Cardinia Shire, there exists public transport services (e.g. metropolitan train and bus services); but the services was very limited and infrequent. Only three localities e.g. Pakenham, Officer and Beaconsfield were within close proximity to the metropolitan train network and few localities e.g. Pakenham, Officer, Guys Hill, Beaconsfield, Beaconsfield Upper, Emerald, Cockatoo and Pakenham Upper are connected via bus services. The study reveals that about 96% of the employed population used to travel to work by using a car. Only a small proportion of population (see Table 5-4 and Table 5-5) were reside within walking distance from the health care facilities. Due to very limited public transport opportunity, the residents of Cardinia Shire have to largely rely on their own travel arrangement.

6.4 Health care facilities characteristics and spatial variations

In this study, health care facilities were analyzed in terms of spatial distribution of the facilities and population to health care facilities ratio. Three essential health care facilities have been included for this study, i.e. pharmacy, GP/Surgeon clinic and dental clinic. Altogether, 64 health care facilities were located within the Cardinia Shire. Those health care facilities were located only in the large townships of the Shire such as Pakenham, Emerald, Koo Wee Rup, Beaconsfield, Lang Lang, Bunyip where the majority of the population lived. There were 49 localities within the study area; only 9 localities have at least one type of health care facilities including Pakenham, Emerald, Koo Wee Rup, Beaconsfield, Lang Lang, Bunyip, Beaconsfield Upper, Garfield and Cockatoo. Pakenham and Emerald are the only two localities where all those types of health care facilities can be found to exist. Beaconsfield Upper, Garfield and Cockatoo have one health care facility each.

6.5 Spatial accessibility to health care facilities and spatial variations

Spatial variation in the distribution of the population, transportation infrastructure, and the health care facilities, inevitably result in variations in access to health care facilities in the Cardinia Shire. Due to limited and infrequent public transportation services, this study used car based travel distance and driving time o measure spatial accessibility to health care facilities from MB centroids. The study reveals that travel distance via road network to nearest health care facilities e.g.

pharmacy, GP/surgeon clinic or dental clinic varies between 12m and 31.3km (see Table 5-1) and the average distance varies between 3.2km and 6.1km (see Table 5-2). The health care facilities within the Shire are in fact only accessible for a limited number of populations by walking.

Using normalized road network based travel distances to nearest health care facilities, an accessibility index value has been calculated for each MB centroid. Major towns (with health care facilities) and its surrounding localities show a low accessibility index value (indicate high spatial accessibility to health care facilities). Spatial accessibility was relatively high in such localities like Beaconsfield, Beaconsfield Upper, Bunyip, Cockatoo, Emerald, Garfield, Koo Wee Rup, Lang Lang and Pakenham. Since large townships have higher density of population and health care facilities are located within the large townships, it appears that a large proportion (see Table 5-4 and Table 5-5) of total population gets high spatial accessibility to nearest health care facilities in terms of car based driving distances. But a large proportion of dependent population e.g. unemployed and children; low income dwellings or dwellings with less than 2 cars are residing in locations within small towns or away from large towns are suffering from low spatial accessibility to health care facilities. The analysis shows that those populations have relatively low economic resource, low ability to access to health care facilities at the time when they needed.

Spatial clustering analysis have revealed that about 9% of the total population or nearly 4,000 persons are identified (with the Gi* statistic), about 4.5% of the total population or over 2000 persons are identified (with the local Moran's I statistic) and about 5.5% of the total population or over 2500 persons are identified (with the univariate LISA analysis) in disadvantaged locations. Overall, about 2,500 persons are identified in disadvantaged locations in Cora Lynn, Pakenham Upper, Maryknoll and Tynong North with poor spatial accessibility to health care facilities.

6.6 Areas for further research and improvement

A number of areas for further research have been identified during the data collection, data preparation and data analysis phase of this study, including:

1) Better understanding the socioeconomic characteristics of the population in relation to their affordability for and preference to the utilization of health care services e.g. language and gender of the health care services professionals. It is also important to know their acceptable travel distances and travel time to nearest health care facilities. Level of satisfaction with the existing level of availability and affordability for health care facilities would be another important issue to investigate. These issues need to be carefully investigated using a properly designed and conducted questionnaire survey.
2) Accessibility to health care facilities should be characterized in terms of space, time and themes. Availability of health care service or professionals, travel cost, health care service cost and effort to access to health care facilities all needs to be considered simultaneously. Taking spatial, temporal and thematic aspects of accessibility into account simultaneously will enable comprehensive analysis of accessibility. In addition, it is more desirable to offer emphasis on the user's preference on gender and language of the health care service professionals.
3) Incorporating multi-modal transportation in measuring travel distances or travel time. This study assessed car based travel distance and travel time.

A comprehensive analysis incorporating public transportation modes (e.g. bus, trains) and other means of transportation (e.g. walking, cycling) should be conducted to recognize the real state of spatial accessibility to health care facilities.

4) Applying more realistic network analysis settings to improve network analysis settings and get more accurate travel time measurement between health care facilities and their user, by incorporating more realistic edge impedance and turn impedance into the transportation network dataset, and by incorporating time-dependent information in terms of traffic conditions throughout the day, traffic directions and effects of topography.

The areas for further research and improvement are summarized in Table 6-1.

Table 6-1: Areas for further research and improvement

Areas for further research	Specific areas	Method
Population	Users preference e.g. facilities, language and gender of the health care professional etc.	Survey /interview
	Willingness of traveling distance or time to access the healthcare facilities.	Survey /interview
	Users affordability e.g. ability to pay for specific health care service, ability to access to health care service	Survey /interview
Health care facilities	Availability of the service	Data collection and analysis
	Cost of the service	Data collection and analysis
Transportation	Incorporate multimodal transportation e.g. public transport, travel by car or walking	Complex network analysis
Space, time, theme	Spatial-temporal-thematic analysis	Complex spatial-temporal-thematic analysis

In addition, this study used a simple method to measure spatial accessibility to health care facilities. More sophisticated method e.g. two steps Floating Catchment Area (2FCA) may be applied to see if difference will show in the results; and this study used a simple accessibility index to identify disadvantaged locations. Those statistical measures produce slightly different outputs to each other so a comprehensive study is required to identify the reason why those output data are different.

6.7 Conclusions

This study investigated spatial accessibility to health care facilities by the local communities of Cardinia Shire and developed a GIS based approach to the identification of disadvantaged localities in terms of spatial accessibility to health care facilities. Through the investigation, this study established that within the Cardinia Shire there exist spatial variations in the distribution of its population and associated demographic and socio-economic characteristics. Health care facilities were not evenly distributed across the study area, but concentrated in a few large towns. There were 49 localities within the study area; and 40 of them have no health care facilities available. The ratio of doctor to population in Cardinia Shire is lower than the Australian commonwealth benchmark of 1:1400, and also varies between localities. A large proportion of the residents have to travel a long way to access the health care facilities. Some local communities' accessibility to health care facilities is very poor, as public transport is both inadequate and infrequent due to inadequate and low frequent availability of the public transportation services. Most of the local population in the Cardinia Shire use their own cars or organize other alternative ways to access health care facilities.

In Cardinia Shire, health care facilities were distributed in such a way that only a small proportion of the population (see Table 5-4 and Table 5-5) can access those facilities by walking. Large proportion (see Table 5-10 and Table 5-21) of the population, reside beyond 10km of travel distance or 10 minutes of driving time to nearest health care facilities. More than half of the total population resided within the mean travel distance (Table 5-7) and almost a similar proportion reside within the mean travel time (see Table 5-18). Socio economic conditions of the residents above mean travel distance or travel (driving) time from nearest health care facilities are relatively poor in contrast with those people who reside within the mean travel distance or mean travel (driving) time. A combination of low spatial accessibility to health care facilities, higher proportion of dependent population, low income dwellings or dwellings with less than 2 cars result in more difficult situation for the local residents in those disadvantaged locations or areas.

It is one of the fundamental human rights to get adequate, fair and easy access to health care service at the time needed. In reality, absolute equal spatial accessibly is not always achievable but it is possible to plan and build a system of health care facilities in such a way so that it allows the highest spatial accessibility for a maximum number of the population. It is important to give priority and measure how fair and how easy to access to the health care facilities would be if there are any future development or further expansion of the localities and build residential areas. It is also important to look at not only the distribution of health care facilities and population, but also the socio-economic conditions of the residents within the surrounding areas. To establish new health care facilities in most suitable location or relocate some facilities could be a solution to those disadvantaged communities.

Because a large number of the population reside in the surrounding localities to the large towns, centralizing health care facilities into large towns may facilitate the residents in the nearby localities in a way that they can have a choice of selecting an appropriate service for them and ensures that a maximum proportion of the population gets highest possible spatial accessibility to health care facilities. However, spatial accessibility may be poor for residents live in areas in absence of adequate transportation services even when the travel distance is only a few kilometres. The improvement of overall accessibility to health care facilities in the Cardinia Shire can be achieved by either improving the public transportation system or re-allocating health care facilities according to the spatial and socio-economic needs of the resident population of the Shire.

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Appendix A. Ahamd et al 2009

Ahmad, S. Liu, G. and Engles, B. (2009) A simple GIS based method for transferring census data from CCDs to MBs.

This article was peer reviewed by two independent and anonymous reviewers

A SIMPLE GIS-BASED METHOD FOR TRANSFERRING CENSUS DATA FROM CCDS TO MBS

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ABSTRACT

More spatially distributed description of local communities' characteristics is desirable for many applications using census data, such as the characterization of spatial accessibility to healthcare services by local communities in urban fringe zones. Pre-2006 census data available from the Australian Bureau of Statistics (ABS) enables us to do this at the Census Collection District (CCD) level, and the 2006 census data brings an opportunity for us to do so at the Mesh Block (MB) level. However, many attributes currently available at the CCD level are not yet presented at the MB level, and it is not likely for ABS to make these CCD-level attributes available at the MB-level in the foreseeable future. In order to produce a useful description of local communities' characteristics at the MB-level, it is necessary to transfer these CCD-level attributes to the respective MBs. Many areal interpolation methods have been developed to transfer data between areal units of incompatible boundaries. Using the data available at both the CCD and the MB levels, a simple GIS-based method for transferring CCD-level data to the respective MBs is developed. Experiment results indicate that the method developed is efficient and robust. The method presented in this paper can be useful for many applications using census data, including the spatial characterization and optimization of public health and socio-economic conditions.

Ahmad, S., Liu, G. and B. Engels (2009). A Simple GIS-based Method for Transferring Census Data from CCDs to MBs. In: Ostendorf B., Baldock, P., Bruce, D., Burdett, M. and P. Corcoran (eds.), Proceedings of the Surveying & Spatial Sciences Institute Biennial International Conference, Adelaide 2009, Surveying & Spatial Sciences Institute, pp. 513-521. ISBN: 978-0-9581366-8-6.

INTRODUCTION

Transferring census data between incompatible source and target areal units by means of aerial interpolation (Reibel & Bufalino, 2005) is a challenging task (Smith & Goodchild, 2006) and important to many applications (Flowerdew & Green, 1992; Reibel & Agrawal, 2005), such as spatially refined characterisation of socio-demographic conditions and trends for supporting evidence-based resource location-allocation planning and optimisation of public service provision. More spatially distributed description of local communities' characteristics is desirable for many applications using census data, such as the characterization of spatial accessibility to healthcare services by local communities in urban fringe zones.

In Australia, available pre-2006 census data enables a spatially distributed description of local communities' characteristics at the Census Collection District (CCD) level, and the 2006 census data enables a spatially distributed description of local communities' characteristics at the Mesh Block (MB) level. A CCD is the smallest unit used for collecting and recording Census data prior to the 2006 Census, with about 220 dwellings in urban areas and reduced number of dwellings in rural areas as population densities decrease. MBs are new micro level standard and pervasive geographical units introduced by the ABS for the 2006 Census, identified by their predominant land use (residential, commercial, agricultural, parkland etc.) and each contains between 30 to 60 dwellings in residential areas. There are 9310 CCDs and 71872 MBs defined throughout Victoria for the 2006 Census.

Many attributes currently available at the CCD level are not yet presented at the MB level, and it is not likely for ABS to make these CCD-level attributes available at the MB-level before next Census in 2011, when the MBs will replace the CCDs to become the new basis of the Australian Standard Geographical Classification (ASGC) for the publication of the complete range of ABS spatial statistics (ABS, 2008). In order to produce a useful description of local communities' characteristics at the MB-level, it is necessary to transfer these CCD-level attributes to the respective MBs, at least for the period before next Census.

The following sections will present a simple GIS-based method for transferring CCD-level data to the respective MBs, using the data available at both CCD and MB levels from the case study area, Cardinia Shire, located on the southeast fringe of metro Melbourne, followed by some experimental results and discussions for further improvements of the developed method.

Study Area and Data

The case study area is about 1281 km^2, covers the whole Cardinia Shire, located between 37° 85′south to 38° 33′ south and 145° 35′east to 145° 76′east, about 60 km to the south-east from Melbourne CBD (Fig. 1a). More than 90% of the total land cover of this area is being using as agriculture and parks lands where only 6.13% is residential.

According to the 2006 Census and 2007 VICMAP data, (a) there are about 57,091 persons living in 21,075 household dwellings, with an average dwelling size of 2.7 persons per dwelling; (b) there is homogeneity in population distribution and in different age group by sex (Fig. 1b) ; (c) the Shire has a population density of 44.57 persons / km^2 and a dwelling density of 16.45 dwellings / km^2; (d) major residential centres or localities within the Shire include Pakenham, Koo Wee Rup, Lang Lang, Bunyip, Cockatoo, Beaconsfield, Emerald and Gembrook; and (e) there are 32,531 individual addresses, 637 mesh blocks, 74 CCDs, 49 localities, and 18 postcode areas identifiable within the study area.

Both digital boundaries and census statistics have been sourced from the ABS websites (http://www.abs.gov.au/). CCDs have more attributes (e.g. age, sex, income, education, car ownership, etc.) available for the characterisation of community profiles but MBs have only three attributes available: land use category, total number of dwellings, and total number of persons. As shown in Fig. 2, the following spatial relationships between CCDs and MBs can be observed: (a) a CCD may contain a set of MBs completely or partially, (b) a MB may be completely or partly within a specific CCD, and (c) a MB may belong to one or more CCDs.

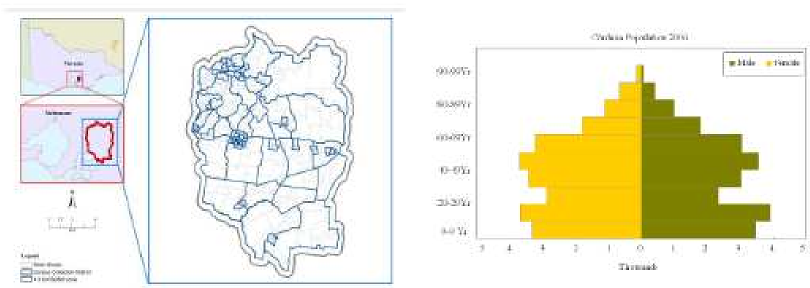

Fig. 1: The Cardinia Shire (a) and its population pyramid (b).

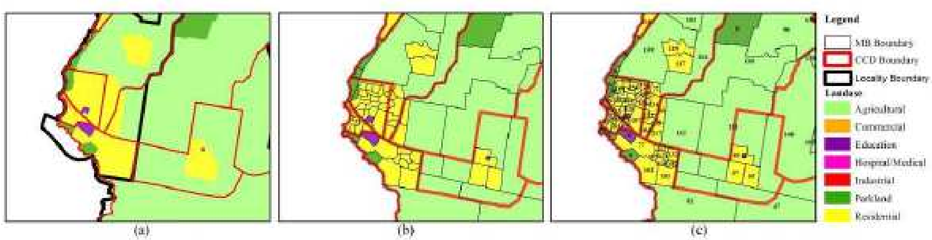

Fig. 2: Incompatible areal units: (a) Locality and CCD boundaries with colour coded land use categories; (b) CCD and MB boundaries with land use categories; (c) CCD and MB boundaries with land use categories and MB-level attributes (e.g. population count).

Methodology

Flowerdew & Green (1992) describe an approach to areal interpolation of normally distributed data where two zone-boundary layers are intersected and thus generated "intersection zones" fragments. Each fragment has a unique pair of source and target zone and their estimates are calculated by multiplying the source-zone count by the ratio of the area of the fragment to the area of the source zone, to enforce "volume preserving" or "pycnophylactic property" (Tobler, 1979).

Given the 2006 census attributes available at the CCD level and MB level, the volume preserving principle can be implemented as follows:

a. The total number of persons in a CCD is same as the sum of total number of persons in the associated MBs, i.e.

$$CCD_i^p = \sum_j^n MB_{ij}^p$$

where CCD_i denotes the i^{th} CCD, MB_{ij} the j^{th} MB associated with the i^{th} CCD, n the total number of MBs in the i^{th} CCD, and p person count; or

b. The total number of dwellings in a CCD is same as the sum of total number of dwellings in their respective MBs, i.e.

$$CCD_i^d = \sum_j^n MB_{ij}^d$$

where d denotes dwelling; or

c. The total quantity of a specific census variable in a CCD is same as the sum of total quantity of a specific census variable in their respective MBs, i.e.

$$CCD_i^v = \sum_j^n MB_{ij}^v$$

where v denotes a specific census variable.

In addition, the following ratio consistency can be assumed:

a. The MB *vs* CCD ratio of the quantities for a specific census variable is consistent to the corresponding population ratio, i.e.

$$\frac{MB_i^p}{CCD_i^p} = \frac{MB_{ij}^v}{CCD_{ij}^v}, \text{ or}$$

b. The MB *vs* CCD ratio of the quantities for a specific census variable is consistent to the corresponding dwelling ratio, i.e.

$$\frac{MB_i^d}{CCD_i^d} = \frac{MB_{ij}^v}{CCD_{ij}^v}.$$

Spatially, it is assumed that:

a. CCD level quantities are distributed among the associated MBs on an area-weighted basis, i.e.

$$CCD_{ii}^{p} = \sum_{j}^{n} a_j MB_{ij}^{p}$$

where a_j denotes the area of j^{th} MB in CCD_i; or

b. CCD level quantities are distributed among the associated residential MBs on an area-weighted basis, i.e.

$$CCD_{ii}^{p} = \sum_{j}^{n} b_j MB_{ij}^{p}$$

where b_j denotes the area of j^{th} residential MB in CCD_i; or

c. CCD level quantities are distributed among the associated residential MBs weighted by their population ratio, i.e.

$$\frac{MB_i^p}{CCD_i^p} = \frac{MB_{ij}^v}{CCD_{ij}^v} \quad \Rightarrow \quad MB_{ij}^v = \frac{MB_{ij}^p}{CCD_{ii}^p} CCD_i^v$$

In this study, CCD level quantities are distributed among the associated residential MBs weighted by their population ratio, and the total quantity of a specified variable in a CCD should equal to the sum of total quantities of the associated MBs, i.e.

$$MB_{ij}^v = \frac{MB_{ij}^p}{CCD_{ii}^p} CCD_i^v \text{ and } CCD_i^v = \sum_{j}^{n} MB_{ij}^v$$

Results

The 2006 census data on total population and 0-4 years of age population for 5 selected CCD and the total population for the associated MBs is used to illustrate this simple GIS-based method for transferring CCD level quantities (0-4 year age-group population, in this case) to associated MBs (Fig.3 and 4).

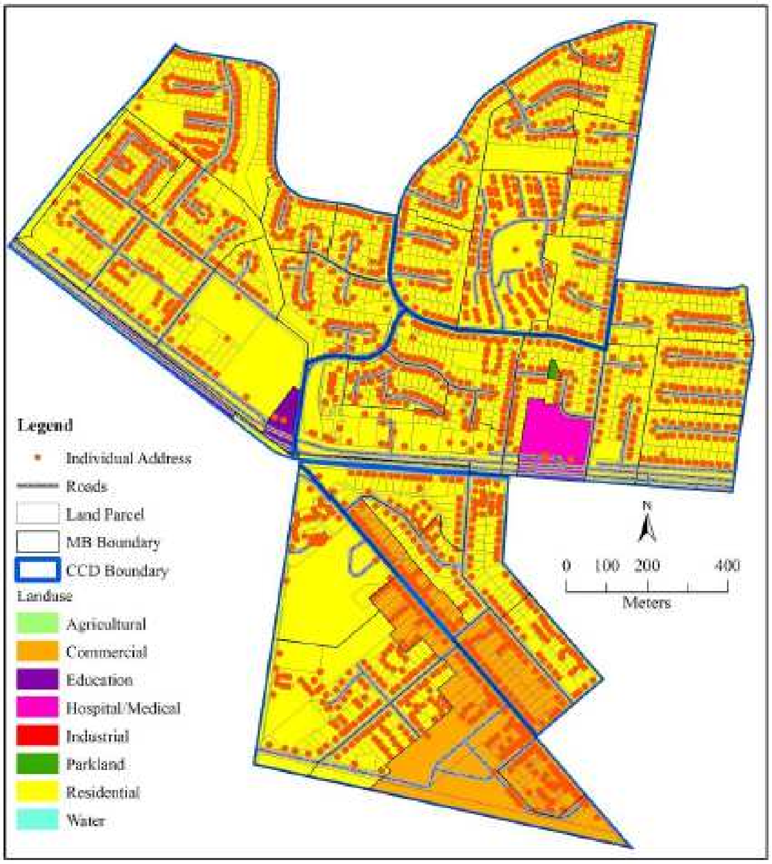

Fig. 3: Map shows 5 CCDs with their associated MBs, land parcels, roads, address locations and land use categories.

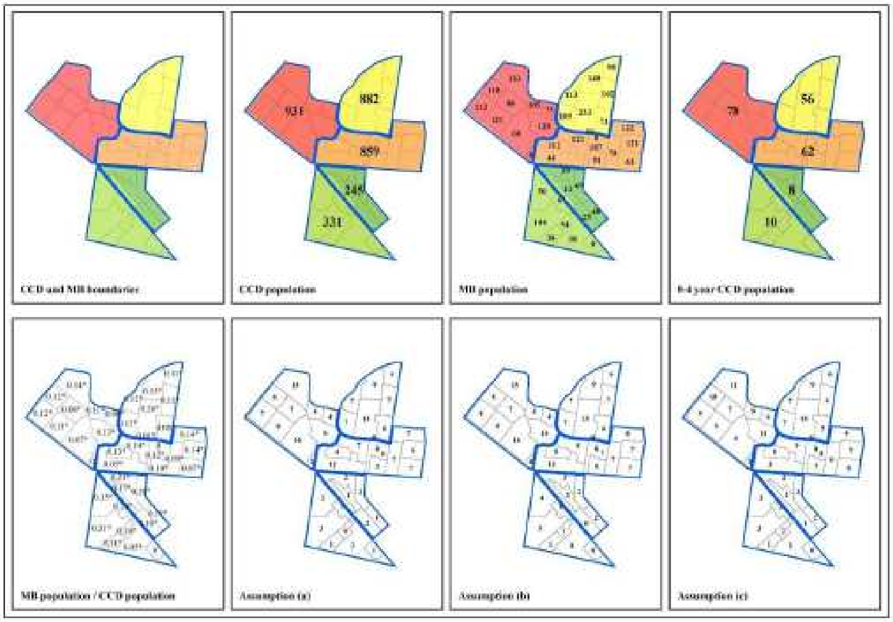

Fig.4 shows the CCD and MB boundaries (a), the CCD level total population (b), the MB level total population (c), the CCD level 0-4 year age-group population (d), the MB *vs* CCD population ratios (e), the MB level 0-4 year age-group population, weighted by associated MB areas (f), the MB level 0-4 year age-group population, weighted by associated residential MB areas (g), and the MB level 0-4 year age-group population, weighted by MB/CCD population ratios (h).

This simple method can be implemented easily in Excel as shown in Tab.1.

Tab. 1: Transferring motor car ownership* from CCDs to associated MBs

CCD ID	MB ID	Landuse	MB Population	MB Dwelling	CCD Population	CCD Dwelling	Motor Car owned (CCD)	MB level estimation Using dwelling‡	MB level estimation Using Population‡
2340301	20100340000	Residential	103	46	667	239	25	5	4
2340301	20102330000	Residential	153	45	667	239	25	5	6
2340301	20101610000	Residential	92	31	667	239	25	3	3
2340301	20101060000	Residential	71	29	667	239	25	3	3
2340301	20100720000	Residential	105	36	667	239	25	4	4
2340301	20100530000	Residential	143	52	667	239	25	5	5
2340301	20702980000	Parkland	0	0	667	239	25	0	0
Total 0-4yr population in CCD 2340301								**25**	**25**

* note that actual data is not shown in this table. ‡ Integer format

Fig.5 compares spatial patterns of CCD level and MB level 0-4 year age group population densities. The kernel density suraces (search radius = 4000, output cell size =

100 m^2) are created from CCD centroids and MB centroids, using 0-4 year age group population given for the CCDs and estimated for MBs, respectively. Clearly, the density surface generated from the estimated MB population provides a spatially refined and more accurate 0-4 year age group population density representation.

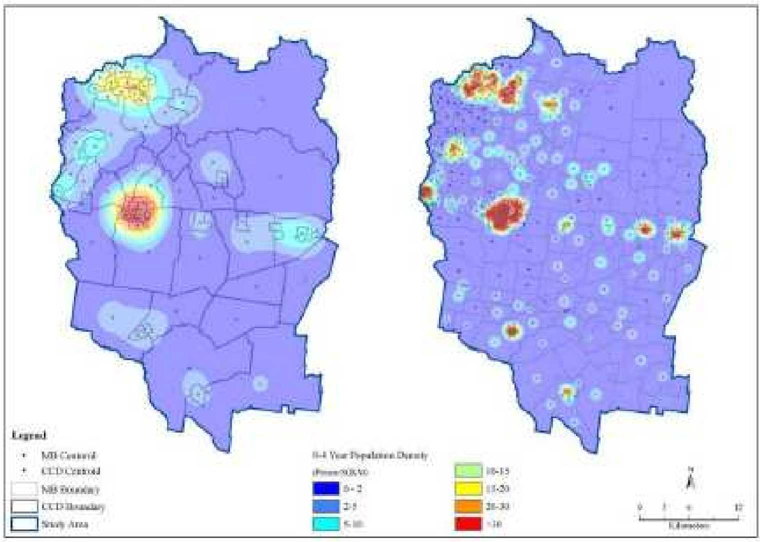

Fig. 5: 0-4 years population density for CCD (left) and MB (right)

As a reference, Fig.6 compares spatial patterns of CCD level and MB level total population densities, created with identical procedures and parameter settings as used in generating Fig. 5.

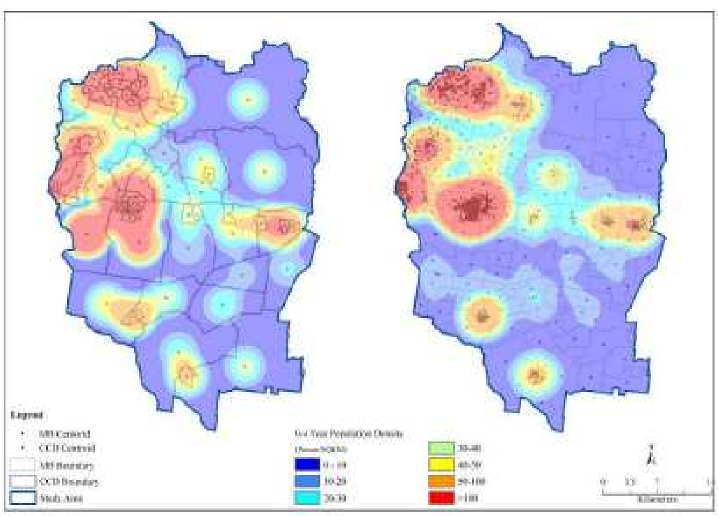

Fig. 5: Population density for CCD (left) and MB (right)

Discussions and Conclusions

The method is designed with the census attributes available at both the CCD level and the MB level, guided by the 'volume preserving' principle' and based upon the assumed consistency between MB/CCD ratio of total population and MB/CCD ratio of other census quantities.

The simple method developed in this study is very robust for transferring ABS census data from CCD level to MB level, and is easy to implement within a GIS. The estimated spatial pattern of census quantities (e.g. the 0-4 year age group population, in this case) resolved at the MB level provides a spatially much refined representation when compared with the patterns at the CCD level.

This method provide a useful tool for researchers, planners and public policy analysts to characterize population and relevant attributes at refined spatial resolutions, to gain more realistic spatial patterns and hence a better foundation for assessing spatial accessibility to various human services, including healthcare services, by local communities. In cases with clear coincidence of CCD and MB boundaries, the method can be implemented even within the Excel environment. In cases involving intersections of CCD and MB boundaries, topological overlay is a required GIS operation to apportion CCD area among associated MBs.

It should be noted that the method gives different results depending on which MB attribute (population or dwelling) is used and how land use category is treated, and that the assumed consistency between MB/CCD ratio of total population and MB/CCD ratio of other census quantities deserve further verification.

Acknowledgement

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