The New Zealand accessibility analysis methodology
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An important note for the reader

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Steve Abley dedicates this research to Malcolm Douglass, who has given his professional career to creating stronger communities through better integrating transport and land use.

Contents

Executive summary

It was an objective of this research to answer the question 'what is accessibility and how might it be measured and quantified in New Zealand?' Accessibility (and accessible) is often a confusing term because it is sometimes used to describe when access is or is not achieved for people with mobility or sight impairment, eg to a building, and it is often used to infer the ease of reach to a certain destination, eg to a location via a particular mode of transport that might be some distance away.

This research is concerned with the wider definition of accessibility and although one element is 'capability', eg a barrier that might restrict access to people with mobility or sight impairment, there are two other elements, 'opportunity' and 'mobility', that need to exist for true accessibility to be present. It is when these three dimensions are present that accessibility can be understood, measured and quantified.

This research proposes that accessibility in New Zealand is defined as 'The ease with which activities, either economic or social, can be reached or accessed by people'.

The research has been prepared against a background of UK and European, and to a lesser extent US and Australian experience. These overseas experiences have been compared with existing New Zealand policy, practices, capability, need and data. An overriding conclusion of the research is that by better understanding accessibility there is the potential for a step-wise improvement for how transportation and land use can be better managed and integrated. Improved understanding of accessibility also has the potential to guide policy makers to deliver improved accessibility both by clarifying current implicit accessibility policy, and by setting out new explicit policies – accessibility also needs to be considered as its own area of study.

The research has identified that traditional transport demand models do not answer all the questions required of today's decision makers, and accessibility assessment (and specifically accessibility modelling and analysis) provides a new perspective for old problems. Consequently the research includes a methodology to quantitatively measure accessibility that takes into consideration different modes of travel (walk, cycle, private motor vehicle etc), travel behaviour (logistic decay functions), destinations (origin or destination based), activities (consumed or supplied) and multiple opportunities (saturations). The research also describes the different types of indicators such as threshold, continuous and composite indicators and the audiences most suited to each indicator type.

Although accessibility modelling calculations can be undertaken manually, given the range of potential travel that accessibility modelling attempts to assesses, ie what travel 'could' be undertaken rather than 'would' be taken, the calculations are best automated within a computer. Given the need for specialised software to undertake these types of calculations various overseas programs were examined and one program briefly tested. It was concluded that given New Zealand's data constraints, the spatial nature of the calculations and the flexibility provided by geographic information systems (GIS), the research settled on a GIS providing the best overall solution and hosting location for the resulting calculations and maps.

Consequently the pilot accessibility assessment of Christchurch, New Zealand was undertaken within a GIS and the various calculation methods and scenarios examined to understand the responsiveness of the proposed accessibility methodology to change. This included measuring the change in accessibility with the addition of a new land use, ie a new hospital, and the change in accessibility with the addition of new infrastructure, eg a new pedestrian, cyclist and vehicular bridge. This also showed the spatial scalability of a GIS where the methodology can be run at both a meshblock (a group of households) and an individual (household) level without modification.

Given the new and evolving nature of accessibility assessments the study identified a number of potential areas for refinement and further research. These are broadly categorised into two types of recommendations: management and delivery; and development and refinement. Even so, and given the number of recommendations will take several years to implement, the majority of the New Zealand accessibility analysis methodology included in the research is suitably refined for use by practitioners, today.

Further information on accessibility can be found at www.accessibility.org.nz.

Abstract

This research considers land use and transport accessibility drawing on international practice from the UK, Europe, USA and Australia. An objective of the research was to define accessibility and propose a methodology for how accessibility could be measured and quantified in New Zealand, both at a neighbourhood or a wider area such as a suburb, city or region.

The result of the research was an understanding of other countries' experiences developing and setting accessibility policy and the success of those approaches. This is important because if New Zealand chooses to set explicit accessibility policy, the research explains how that might be best achieved.

A second result of the research was the development of a new methodology for calculating accessibility that draws on overseas and improved practice. The new methodology quantitatively measures accessibility taking into consideration different modes of travel (walk, cycle, private motor vehicle etc), travel behaviour (ideally using logistic decay functions), destinations (origin or destination based), activities (consumed or supplied) and multiple opportunities (saturations). The calculation methodology was piloted on Christchurch (a city of some 350,000 people) and the accessibility of every household quantified to a variety of destinations including doctors, supermarkets and schools.

INTRODUCTION TO THIS REPORT

Introduction

Motivation

In part, the motivation for this research was the Land Transport Management Act 2003 and the objective for 'improving access and mobility'[1]. But what is access and mobility and how do these aims relate to other 'accessibility' goals? In answering this question, the research was informed by overseas research, current accessibility analysis practice in New Zealand, and work to develop and pilot a methodology for the assessment of accessibility in New Zealand.

Aims and objectives

The original aim of this project was to develop a neighbourhood accessibility assessment tool, principally for local authority use recognising that it is within local neighbourhoods that many best value solutions are not being identified by existing transport planning tools. The new tool would:

- assess how well the neighbourhood provides for residents with differing abilities and needs
- measure access to destinations that provide the services residents need (such as primary schools, retail groceries, doctors' surgeries, sports grounds) by all modes, but especially walking, cycling and public transport.

Furthermore, the accessibility tool should[2]:

- provide clear, objective, quantifiable measures of how accessible an area is by walking, cycling and public transport (preferably compared with car access)
- give sufficient detail to identify the nature of the problems so improvement options can be developed and assessed for all modes
- identify the key obstacles to greater use of active modes in the area
- take into account the quality (attractiveness, legibility) of the walking and cycling routes – not just the access times and safety
- be user friendly and intuitive to use without a large investment in training
- be affordable so councils can use it
- be compatible with other data and complementary projects.

Since the research was commissioned in May 2007, the scope broadened to include development of a methodology for calculating an accessibility score that could be derived for a neighbourhood or a wider area such as a suburb, city or region. It was also important to set this methodology within the context of

[1] Core requirements of regional land transport programmes prepared by regional transport committees (Land Transport Management Act 2003, s14(a)(ii)(C)

[2] Adapted from 'Request for proposal 50_07'

changes in accessibility through building new roads or opening new bus services or railways, or construction of new homes, workplaces, shops and services.

Structure of this report

This report has been divided into three parts. Each part may interest a particular reader's objective or focus although the authors encourage reading the report as a whole, given each part informs subsequent parts.

Each part concludes with a summary except Part 3, which contains a wider discussion and identifies conclusions and recommendations from the research as a whole.

The parts are:

1 **An international perspective of accessibility assessment**

This part identifies the key points to incorporating accessibility assessment into New Zealand policy and practice. It draws heavily on the experience of the UK and also Germany and The Netherlands.

2 **New Zealand accessibility: practice and resources**

This part places accessibility within the New Zealand context including the definition of new terminology, the relationship between traditional transport modelling and accessibility modelling and New Zealand's experience with accessibility modelling so far.

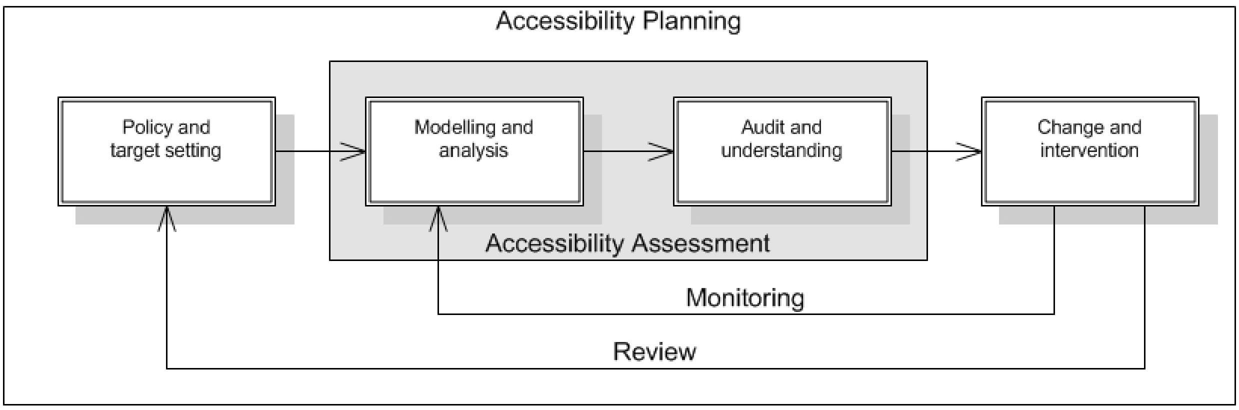
3 **New Zealand accessibility: modelling methodology**

This part introduces a method for calculating accessibility taking into consideration New Zealand travel behaviour. This part also includes the overall discussion, conclusion and recommendations for the research.

Terminology

During the development of this report, terminology in the study of accessibility was identified as inconsistent. The authors have developed the following figure (figure 1) to clarify terms such as accessibility planning, accessibility policy, accessibility analysis, accessibility audits and accessibility interventions. This report is specifically concerned with 'Modelling and analysis'.

Figure 1 Accessibility planning processes



In addition, the report includes a comprehensive glossary (appendix G) to further clarify technical terminology.

PART 1: AN INTERNATIONAL PERSPECTIVE OF ACCESSIBILITY ASSESSMENT

1 Introduction to Part 1

Part 1 of this report summarises the experience of evaluating accessibility in the UK and around the world. It identifies the key points to incorporating accessibility assessment into New Zealand policy and practice.

Drawing on knowledge from countries with experience in accessibility analysis and planning such as the UK, Germany and The Netherlands has revealed a close relationship between an integrated approach to governance and successful integration of accessibility assessments. National policy and top-down governance on accessibility need to aid the development of local schemes and organisations enabling delivery of accessibility improvements.

Although many countries have well-defined policies on accessibility, it is still a growing area of expertise. Accessibility goals have long been stated, and measuring techniques help to define the connections needed for people to access places and opportunities. As each country seeks more integrated approaches to transport management and delivery, methods for evaluating accessibility are developing to support the accessibility policy aims.

Most countries with well-defined national policies on accessibility provide details of accessibility planning requirements for local authorities. In some countries, eg Germany, national government uses accessibility indicators from national analysis to help direct national resources to local authorities with greater accessibility needs. Other countries quantify national targets and goals, such as those in The Netherlands, to encourage transport intensive development in accessible locations. In all countries with well-developed accessibility policies, the national government analyses accessibility change over time. This is because without clear measuring techniques accessibility goals are unclear. Therefore accessibility measures can be used to identify clear goals that relate to wider social and economic aims within national policy.

Accessibility aims are implicit in current New Zealand national policies but these aims are often expressed in terms of connectivity and travel demand. Connectivity and accessibility are two ways of looking at the same challenge, and accessibility is a practical way to define what connectivity means and how it can be analysed and measured. The purpose of making connections through accessibility planning is to ensure the benefits of transport change for people and businesses are explicit. Sometimes the focus on people is most important at a neighbourhood level for access to essential local facilities but there can also be accessibility goals nationally or internationally to ensure specific business sectors have good accessibility to specific markets or resources. Policy development and practical modelling approaches must develop together.

The New Zealand Transport Strategy (MoT 2008)[3] is the longest horizon planning document for transport in New Zealand. Accessibility modelling is likely to be a very helpful tool to achieve New Zealand's Land Transport Management Act 2003 purpose 'to contribute to the aim of achieving an affordable, integrated, safe, responsive, and sustainable land transport system' or, the Land Transport Management Bill's (introduced 13 August 2012) amended purpose 'to contribute to an effective, efficient and safe land transport system that supports the public interest'.

To assist the development of an accessibility modelling methodology, existing transport models in New Zealand can be modified and functionality from accessibility models elsewhere in the world can be transferred to a New Zealand situation. This report explains how by building from best practice to make optimal use of the data available in New Zealand, a bespoke accessibility analysis tool can be developed tailored to the available data and accessibility planning needs in New Zealand.

1.1 Structure of Part 1

The remaining chapters of Part 1 are as follows:

Chapter 2 discusses how accessibility assessment can fit into government policy using a cross-sectoral approach based on experience in the UK and Europe.

Chapter 3 provides an overview of accessibility indicators and their use in practice. It also discusses accessibility indicators, deterrence factors, the steps involved in calculating accessibility and how accessibility can be reported.

Chapter 4 outlines accessibility modelling approaches and the capabilities of existing transport and bespoke accessibility models.

Chapter 5 suggests a practical approach for implementing accessibility assessment in New Zealand based on the implementation of a comprehensive accessibility framework. It describes how model structure, indicators and evaluation might be tested and monitored in the New Zealand context.

Chapter 6 provides conclusions to Part 1.

[3] The New Zealand Transport Strategy (NZTS) is a non-statutory document released by a previous government that uses a planning horizon to 2040 that has been largely superseded in the short term by subsequent policy decisions. The current government supports the overall intent of the NZTS; however, it is less relevant as a practical guide to how New Zealand is responding to the issues facing the transport sector in the immediate term. Connecting New Zealand (MoT 2011) is a more relevant non-statutory document summarising the government's transport policy and intentions over the next decade and is informed by other government non-statutory documents that have different time horizons, including the National Infrastructure Plan that has a planning horizon of 2030.

2 Concepts

2.1 Policies and indicators

Measuring accessibility without first clarifying the policy on accessibility could inadvertently create unintended policies. The Audit Commission (UK) (2000, paragraph 8) notes 'If an organisation does not measure what it values, it will end up valuing what can be measured'. Transport markets and public agencies have a strong tradition of measuring the number of travellers and vehicles, but have been less effective at measuring gaps in coverage and whether the network coverage allows customers access to the places where they need to travel. Across the world it is recognised there is a need to focus on transport investment, to connect up the economy and society. This makes the purpose of transport investment clearer, not just connecting New Zealand for competitive access to international markets, but ensuring that a child has safe access to the school in their neighbourhood.

The starting point for measuring accessibility is therefore to establish to what extent policy is already in place. A review (Chapman and Weir 2008) showed although many statements were made in policy documents about improving accessibility and mobility, the terms were used without clear definition. The review suggested further work was needed to clarify accessibility policy, with the Ministry of Transport coordinating action and liaising with other ministries and regional authorities on policy development.

In order to progress these actions within the context of improving New Zealand accessibility, three main aims have been identified as follows:

- Harmonise policy across ministries and government including the specific roles at national, regional and local levels. This would include identifying and setting appropriate accessibility indicators, standards and targets. This is an ambitious goal, but even if full policy harmonisation is not achieved, it is still practical for different ministries to agree on shared or overlapping goals as has been demonstrated in the UK (DHC and UoW 2004).
- Specify approaches for measuring accessibility within transport planning and appraisal. This would define the role for accessibility planning as a diagnostic tool to help understand the impact of proposed transport changes on people and businesses including incorporating accessibility modelling within regional transportation models.
- Ensure all needs are met by identifying specific action required by location, age, culture and gender.

Policy change needs to be carefully managed to ensure balance between the political, technical and economic impacts. Rebalancing mobility and accessibility aims may have major implications for investment programmes. It takes time to manage this change to ensure the new approaches are politically acceptable and affordable.

In most countries with well-defined accessibility policies, eg The Netherlands, Germany and the UK, national accessibility policy defines the detailed accessibility planning requirements for local authorities, rather than explicit quantified national targets and goals. In these countries national government also supports and undertakes analysis of accessibility change over time. Accessibility measures can then be used to identify relationships with wider social and economic trends informing national policy development (Hilber and Arendt 2004).

2.2 National, regional and local policy

The most common approach to developing national accessibility policy is to emphasise access to mobility (eg in the USA (FHA 2006), Canada and Australia) (Litman 2003). Such policies deliver targeted actions relating to groups of people who suffer from low mobility (eg facilities for people with physical disabilities, and subsidies for transport costs). The attraction of these policies is they do not involve other sectors since they relate solely to the transport sector. Although access to transport is a useful part of the accessibility policy mix, more integrated policies and measures are also needed. Policy on accessibility crosses sectors and modes, and integrated planning is enabled by measures which concentrate on attributes of people and places, rather than simply the transport system. Also by planning improvements for people and places accessibility planning delivers a focus on sustainable and inclusive neighbourhoods.

It is through the development of detailed local policies that accessibility assessments have been most widely used to deliver these integrated approaches. This recognises top-down policies cannot succeed without bottom-up ownership from local areas.

2.3 A cross-sector approach

Assessing accessibility has implications well beyond transport. Health, education and other departments have policies and statutory responsibilities for ensuring access. Ideally transport policies should be compatible with these, but this is rarely achieved in practice without an accessibility planning process to manage the working partnership (FIA Foundation 2004).

Non-transport departments do not generally have well-developed policies and mechanisms for improving accessibility, and responsibility for targeted action is generally perceived to be predominantly a transport issue. Leadership from within the transport sector is therefore needed to tackle the barriers to accessibility assessment.

Accessibility indicators have been widely used in research for many decades but their breakthrough into policy has been more recent due to the growing importance of policy-driven agendas for sustainable development and social inclusion (SEU 2003; Scottish Executive 2000b). These agendas require cross-sector working but issues associated with this include:

- Cross-sector indicators are not wholly within the control of any one policy-making department, eg a health department might set a target that 90% of the population should be within 30 minutes of a health centre but experience shows if road congestion grows making the target unachievable then the target tends to be abandoned rather than cross-sector action being pursued to deliver change.
- Funding streams and progress indicators are closely linked. Accessibility, however, is not dependent on action in any one policy area but reflects both transport and other factors.
- Accessibility is a transparent and user-oriented way of measuring transport which can be sensitive for other sectors if problems arise, eg it will not always be possible for accessibility to improve for everyone so transparent measures can make the process of managing the politics of winners and losers more difficult.

Accessibility planning defines the processes that have been put in place to manage cross-sector working and close the policy gap (SEU 2003). By identifying manageable goals, and using partnership approaches between transport and non-transport departments, the aim is that the long-term decline in accessibility to local services can be tackled.

It should be noted non-transport agencies and departments such as those concerned with health and education will only participate in such partnership approaches if they also have a favourable national policy context within which to operate. The UK has made particularly notable progress in recent years in this regard. The national accessibility planning framework has been delivered across all policy departments and this has been underpinned by audits of accessibility-related policies in health, education, regeneration, land use planning and other policy areas.

3 Indicators

3.1 Dimensions of accessibility indicators

Definitions of accessibility include three key elements:

- The category of people or freight under consideration: each section of the population has specific needs and desires to be involved in defined activities.
- The activity supply point: opportunities are defined in terms of the land use supply which would allow any individual to satisfy their desire to participate in the activity under consideration.
- The availability of transportation and connections: this defines how an individual could travel to reach the relevant facility or make contact through electronic networks. In assessing the transport options it needs to be recognised that all stages of each possible journey by each available mode must be taken into account.

3.2 Person and opportunity types

Factors which define the type of person or traveller include:

- mobility, eg car owner/driver, physical and sensory disability
- employment status, eg unemployed, economically active, job seeker
- age, eg retired, adult, child
- cultural factors, eg gender, ethnicity, faith
- responsibilities, eg carer, lone parent.

The type of opportunities depends on whether origins or destinations are being considered:

- Origin accessibility considers the opportunities available to an individual or a business. The opportunity term is therefore usually based on the land uses at alternative destinations.
- Destination accessibility considers the catchments for a destination. The opportunity term is therefore usually based on the land uses and type of person or traveller at alternative origins.

Each section of the population has specific needs and desires to be involved in activities. These activities are represented as types of opportunities and defined in terms of the land use supply and the location and timing of a range of local services and facilities, which would allow any individual to satisfy their desire to participate in the activity under consideration. Typical activities include:

- employment, education and training – employment locations, job centres, childcare facilities, nurseries, schools, colleges, universities, training centres
- health and social – GP surgeries, health centres, hospitals, dentists, social security offices, drop-in and day care, centres, youth services, citizens' advice bureaux, legal services, etc
- shopping and leisure – shops/shopping centres, cinemas, theatres, sports centres, outdoor activity opportunities, centres for religious activity, pubs, clubs, post offices, financial services, etc.

There are many possible combinations of person types and land uses for both origin and destination (OD) accessibility. It is clearly not feasible to look at all such accessibility issues since the large number of combinations of people groups and trip purposes would not lead to a clear understanding of the accessibility issues. This emphasises the importance of weaving policy aims through behaviourally robust indicators to make the approach useful and understandable in practice.

3.3 Deterrence factors

A deterrence factor is some form of barrier to transportation, for example, time, cost, reliability, safety and security, physical features, quality, environment and information available.

The aim is to represent each deterrence factor or barrier as they are perceived by each population group. This must include the relative deterrent effect of different types of travel, and the costs associated with each (eg the greater deterrent effect of time waiting for a vehicle when compared with the same time spent travelling in a vehicle). Deterrence factors can be categorised as in table 3.1.

Table 3.1 Deterrence factors

Element	Factor
Time factors	• Travel time including walk time, wait time and in vehicle time • Scheduling of activities and transport services by time of day • Time budgets available to each population group for each trip type
Cost factors	• Public transport fares • Fuel and vehicle costs • Affordability for the people concerned
Reliability	• Uncertainty about journey times • Uncertainty about journey quality, eg availability of a seat
Safety and security	• Real and perceived security • Barriers during hours of darkness such as lack of street lighting • Real and perceived safety at all points in the journey including interchanges between modes • Presence of road crossing facilities • Speed limits
Physical features	• Kerbs and physical obstructions • Steep hills and topographic constraints • Surfacing and maintenance
Quality and environment	• Attractiveness and aesthetics of walking routes • Opportunities for shelter from weather and for rest points • Comfort of waiting areas and vehicles • Assistance and helpfulness of public transport staff • Support services when travelling, eg catering
Information and booking	• Information available to plan journey • Time spent planning and booking journey • Availability of information during journey

Although these factors are presented separately it should be noted that eliminating one barrier to accessibility will not improve access if other barriers remain (DHC 2002). It is therefore usually necessary to look separately at the deterrence factors by people group. For accessibility to be improved, all relevant barriers for the people group being considered need to be overcome. This means public transport networks and network coverage is identified as an output from accessibility analysis rather than an input to the analysis.

Many trips will involve a combination of several modes, and for non-car available trips, the car options are excluded from the calculation. For example, a car available trip to a city centre from a rural area may involve a car leg to a park and ride site, a bus leg from the edge of the city to the centre and a walk leg from the bus terminus to the destination. The non-car available alternative would consider only the public transport, walking and cycling options to reach the city centre.

Operational factors, such as system capacity and congestion, need to be included in the analysis when appropriate.

The range of issues that can potentially be included in accessibility measures is broad and the number of accessibility indicators needed to represent people's experiences could be very high. Practical application of the measures depends on selecting the critical issues and measures to capture the significant effects.

3.4 Accessibility reports

There are three main ways of structuring the reporting results generated by accessibility modelling: threshold, continuous and composite reports.

3.4.1 Threshold reports

Threshold reports simplify measurement in terms of defined policy or presentational goals. Thresholds that relate to these goals can be in time, distance and cost, number of people and scale of opportunities that can be reached. These reports can show the number or percentage of a population that can access a destination type within a specified time, cost or distance threshold. Alternatively they can show the travel time, cost or distance required to reach a defined set of opportunities (eg childcare, work and food shopping). Threshold reports are the most common and frequently used of indicators in accessibility planning because they link measuring techniques with defined goals. The destinations that can be accessed by different modes within the threshold can also be aggregated to produce results for a single origin or destination. Threshold reports use a simple yes–no approach to define whether a policy or other goal is met. A threshold report can answer a question 'How many people can reach a doctor within 30 minutes of travel by public transport?'

3.4.2 Continuous reports

Continuous reports avoid the use of thresholds by using algorithms based on observed travel behaviour or other criteria to represent the separation between origins and destinations. The reports record the number or percentage of a population with access to a destination type, and weight the population closer to the destination higher than a population that is further away. The algorithms are often negative exponential or weighted logistic decay equations calibrated and fitted to observed behaviour from trip length distribution data. Or said another way, destinations that are further away from an origin are assigned lower weights reflecting the attraction of each destination, with remote destinations receiving less and less weight until they become insignificant to the overall measure of accessibility.

3.4.3 Composite reports

Composite reports are user-defined combinations of threshold and continuous reports or other measures. Composite reports combine accessibility scores for a variety of destinations and populations. For example, combining the accessibility of primary and secondary schools creates a composite score for 'education' in a given area and/or population. Accessibility maps produced for composite reports could involve a combination of service areas, colour gradients and isolines.

3.5 Experience of accessibility indicators in practice

There are long-standing examples of accessibility indicators in many countries (eg regeneration in Germany, land use planning in The Netherlands). This discussion concentrates on the recent experience of indicator development in the UK which sought to draw from longstanding international practice (Scottish Executive 2000a; SEU 2003) and establish a culture of accessibility measurement at national, regional and local levels across the country. Interest in accessibility indicators continues to grow in Europe and the USA and many of the same issues have emerged as are found in the UK experience. The UK has made very substantial progress with:

- accessibility indicators agreed between government departments[4]
- regional and local indicators developed through working partnerships.

At all levels, data availability is one of the most important constraints. The selection of indicators is a balance between the optimal representation of accessibility problems and the data which is readily available, or can easily be collected.

Table 3.2 shows the indicators in England covering education, health, employment and shopping trip purposes. The lack of indicators covering leisure trips is addressed in Wales where there is a wider range of trip purposes to sports and leisure facilities, but in Scotland only education, health and shopping are included.

The measures each have a target group at the origin and use both threshold and continuous deterrence functions for travel time. The thresholds set in the stepped deterrence functions are based on the distribution of observed travel time from the national travel survey (DHC 2004). The continuous functions are based on a 'Hansen' indicator (Hansen 1959) which uses a negative exponential distribution in the deterrence function.

Table 3.2 Accessibility indicators published for neighbourhoods in England

Destination definition	Population group from Pupil Level Annual School Census data	Travel time indicator from each residence to each destination category	Indicator showing number of people within defined travel time of a destination and choice of opportunities within defined travel time of each residence location			Modes		
			Deterrence function					
			Threshold (mins)		Contin-uous-			
			Lower	Upper		PT/ walk	Cycle	Car
Primary school	Compulsory school age children (5–10 years)	√	15	30	√	√		√
	Children (5–10 years) getting free school meals		15	30	√	√		√
Secondary school	Compulsory school age children (11–15 years)	√	20	40	√	√	√	√
	Children (11–15 years) getting free school meals		20	40	√	√	√	√

[4] These were called the Core National Accessibility Indicators between 2004 and 2009 while the indicators evolved. Now their development has been completed they are published as Accessibility Statistics.

Destination definition	Population group from Pupil Level Annual School Census data	Travel time indicator from each residence to each destination category	Indicator showing number of people within defined travel time of a destination and choice of opportunities within defined travel time of each residence location – Deterrence function: Threshold (mins)			Modes		
			Lower	Upper	Contin-uous-	PT/ walk	Cycle	Car
Further education – college	Population aged 16–19 years	√	30	60	√	√	√	√
Employees in each COA(a) (no.)	Population of working age (16–74 years)	√	20	40	√	√	√	√
	Population in receipt of jobseekers' allowance		20	40	√	√	√	√
Hospitals with an outpatient department as defined by Department for Transport UK (DfT)	Households	√	30	60	√	√		√
	Households without access to a car		30	60	√	√		√
General Practitioners as defined by DfT	Household working age population (16–74 years)	√	15	30	√	√		√
	Households without access to a car		15	30	√	√		√
Supermarket	Households	√	15	30	√	√	√	√
	Households without access to a car		15	30	√	√	√	√

Note: (a) Census output area

This process generates 59 destination indicators and 38 origin indicators with multiple thresholds being published for each of these:

- The destination indicators describe the number of people in the specified catchment, eg 10,000 households within 30 minutes of a hospital and are published for local authority and transport authority areas and at a national level.
- The origin indicators describe the choice of options available from each origin location, eg 15,000 jobs within 60 minutes and are published for each residential location.

A broad-based analysis has also been used nationally in England to compare access by car with access by public transport and walking, but the analysis is not monitored. However, the ratios of car to public transport accessibility show the locations where public transport improvements have the greatest potential benefits to improving accessibility for both car and non-car available trips, and to identify locations where public transport is unlikely to be competitive for car-owning households.

These national travel time-based indicators are limited by the national data but a much wider range of indicators has been used at a local level including:

- community or social outcomes – standards of accessibility to be defined in absolute terms based on an assessment of society's expectations of basic needs
- comparative measures – compare the distribution of access opportunities by people group and location
- stated perceptions – people's views often reveal needs which have not been identified or measured using other techniques.

Local indicators include the:

- frequency with which each service is accessed (expressed need)
- consequences of the person not being able to access the services (social need)
- concerns of the affected groups about not being able to access the services (stated need)
- importance for equity of some people not having access (comparative need).

A selection of these indicators is shown in table 3.3. Each regional and local authority has established their own range of indicators and national government monitors local performance as much from the local indicators as the national ones. The examples in the table are not consistent across the UK but illustrate the range of indicators currently being used. As authorities develop their accessibility plans and establish data collection mechanisms it is anticipated that reliance on the local indicators will grow relative to the national core indicators.

Table 3.3 Local indicators in accessibility planning

Indicator	Uses
% of population able to reach city centre in 30 minutes	Core indicator to monitor impact of additional bus routes to city centre facilities and services
Number of daily bus journeys to city/ town centre	Monitor changes in bus use to access facilities and services
Number of pedestrian journeys into the town centre/ hospital/ school	Monitor impact of improvements to pedestrian environment, eg improved street lighting
% total bus network served (by vehicle mile) by fully accessible low floor vehicles	Intermediate indicator to monitor progress in target to implement fully accessible low floor vehicles on whole network
Number of bus stops and transport interchanges which meet good practice standards for access by disabled people	Intermediate indicator to monitor progress with target
% of passengers satisfied with bus service (reliability, safety, information, condition, etc)	Monitor impact of improvements, eg improved reliability, information, bus stops
Number of referrals to traffic commissioner of bus reliability problems arising from complaints from users	Intermediate indicator to monitor bus service reliability.
% of jobseekers citing transport as a barrier to employment	Monitor the consequences of changes to transport provision.
% of young people with access to public transport in the evenings and at weekends	Core indicator of access at these times
Cost of bus fare per mile to x destination relative to equivalent petrol cost and taxi fare	Monitor relative affordability of public transport services

Indicator	Uses
Take-up of non-statutory concessionary fares by job seekers/young people/carers/etc	Monitor impact of non-statutory concessionary fare interventions
% of bus stops with travel information displays	Monitor access to information
% job centres/GP surgeries/in receipt of travel information	
Is information available in pictogram/different languages/ Braille/Minicom? Yes/No	
Take up of the hospital travel costs scheme by low-income groups including activity on publicising scheme to these groups	
% of hospitals offering travel information service to patients and visitors	
Accessibility of unemployed residents to regeneration areas (the DfT economic impact reporting accessibility measure)	Monitoring accessibility of new job opportunities for targeted groups
% of population able to access the internet and use a credit card to order home food deliveries	Inform policy on the effectiveness of home delivery systems
Number of incidents recorded on public transport	Monitor effectiveness of measures to reduce crime and fear of crime on and around public transport
Proportion of people who feel unsafe walking in their neighbourhood at night	Monitor effectiveness of reducing fear of crime

3.6 Indicators and accessibility needs

It is necessary to use many different indicators of time, cost, user groups and trip purposes. The UK indicators based on time recognise that time is a necessary condition for access. In addition the local indicators recognise that practical travel times are not a sufficient condition for access and a wide range of other factors may also need to be included. Indicators often require multiple destination constraints (eg access to employment for single parent households should also include time windows for access to childcare). For many practical applications it is therefore necessary to combine indicators into composite measures of accessibility to ensure a manageable number of indicators that reflect all local accessibility needs.

To achieve this requires the following:

- All the indicators must be in the same units.
- The relative importance of each indicator must be clear.

For the UK core national accessibility indicators, travel time is often used for combining indicators as the simplest common metric across all trip purposes. Combined indicators are the total travel time to reach a selection of opportunities. The population catchment and opportunity indicators can also be combined by normalising the indicators but appropriate weightings to allow these units to be combined are different for each policy need. To weight each trip type requires the frequency, consequences, stated concerns and equity issues to be considered.

For example, people may not need to make frequent trips to a hospital, but the consequences of not making the trip could be serious. Lack of equity in access to further education may not be a concern to some economically inactive people, but the consequences of this lack of equity can be to build a life of dependency.

Table 3.4 summarises some of the most important services people need to access, and identifies how this relates to the dimensions of 'need'. This provides an overview of the types of issues that need to be considered.

Table 3.4 Accessibility needs and priorities

Service	Why is it essential			
	Frequency of access required	**Consequences of lack of access**	**Stated concerns of people**	**Equity**
Local shop, shopping centre	High frequency and fastest growing trip purpose	Poor eating habits leading to poor health	Concern about the loss of local stores.	Low-income groups make more frequent short trips and pay more, eg taxis
Post office banking/cash machine, legal services	High frequency	Higher costs resulting from the need to use more costly sources for cash such as pay for use cash machines	Concerns about declining local provision	Low-income groups make more frequent trips and pay more for their banking
Leisure, sports, clubs and societies	Medium frequency	Weak social support mechanisms for people who cannot participate.		Low-income groups spend less time travelling for sport and leisure activities and make less frequent trips than for the population as a whole.
Hospital	Low frequency for most people	High for some services. Core services need to be defined.	People do not generally choose where to live because of proximity to a hospital so transport to hospital is relatively important for accessibility.	Low-income groups pay the highest costs for getting to hospital. Choice in healthcare requires more travel favouring mobile groups.
General practitioner	Medium frequency	Delays in seeking help resulting in greater problems and higher costs.	Largely a concern for low mobility groups.	Poor health and poverty are closely linked.
Community/ day centre/ social services	Frequent for a small number of people	People can become unable to live independently without social interaction.	The type of transport is very important since these services target low mobility groups.	
Schools and colleges	Frequent for those in full time education	Some children are unable to participate in discretionary, non-core activities (eg breakfast clubs, homework clubs and after-school activities).		Fewer trips to colleges from lower income groups.
Childcare and nurseries	Frequent for those with children	Restricted time budgets in single parent families can make access to childcare difficult.		Fewer trips to nurseries from lower-income groups.

Service	Why is it essential			
	Frequency of access required	**Consequences of lack of access**	**Stated concerns of people**	**Equity**
Employment	High frequency for working people	Work is central to social inclusion. The inability to access employment as lower value activities move out of town centres to less accessible locations.	Choice of residence location closely related to employment.	Low-income groups travel less far to work and transport costs can be a barrier to take up of low-paid jobs.

Key points to note from the table are:

- Expectations of society move on, so perceptions change and generally rise. Trip lengths and frequencies have been increasing the most for shopping and leisure trips and the accessibility gap has been growing the most between low mobility groups and others for these trips.
- Low-income groups make trips on a similar frequency to high-income groups for access to most public services. Further and higher education is the main exception to this, but the high degree of choice for this trip purpose makes it more similar to market-based provision than to other public services.
- For access to work and access to private services such as shopping, low-income groups show different travel behaviours from higher-income groups. Lower-income groups spend more time than higher-income groups travelling for shopping and personal business (the largely market-based services), but spend less time travelling to work and education. Low-income groups spend less time travelling for sport and leisure activities.
- The implications of these differences are important for public policy since the consequences of lack of access for some people impact on the whole of society.

The relatively similar behaviour demonstrated for access to public services regardless of income, will be heavily influenced by the way these services are provided (eg travel to school or hospital is still only marginally influenced by consumer choice). In contrast, customer choice has a major impact on market-based provision.

3.7 Accessibility outcomes

Evidence from the USA shows built environments and travel behaviour are closely related (Handy and Clifton 2001). Policy aims which emphasise neighbourhood accessibility have the greatest potential for maximising interaction between people and activities within communities. Where people can access opportunities closer to where they live they do so. They also tend to use slower modes.

Improving access is implicit in most transport planning and infrastructure investment. However this implicit treatment is sometimes insufficient for transport planning since:

- There can be unintended consequences from transport investment. For example, when a road is upgraded to a rural community, the shops and services in the rural community often close (Scottish Executive 2001a) resulting in reduced accessibility for the rural area for some trip purposes.
- The impacts of the change are different by population group and area so distributional effects need to be understood (UK Treasury 2003).
- There is a close relationship between transport supply and demand so both accessibility and mobility need to be considered (Hansen 1959).

- Public acceptability is critical, but technical concepts such as speed/flow relationships and supply/demand interaction are poorly understood by the travelling public. If it is proposed to restrain the supply of opportunities for one mode to improve accessibility overall (eg a pedestrianisation scheme), then it is necessary to describe the impacts on people rather than modes to ensure broad support for the proposal (Halden 1996).

3.8 Managing progress and accessibility audits

The widest application of accessibility indicators has been where there are clear legislative and management structures to support their delivery. In The Netherlands there is a well-established culture of accessibility audits within land use planning (Government of The Netherlands 1994). Accessibility audits for low-mobility groups in place in many countries are underpinned by equity aims recognising the difficulties that people with physical disabilities face (FIA Foundation 2004). In contrast, where neighbourhood audits have been proposed to improve access to local services, but without a delivery framework, there has been limited action (Handy and Clifton 2001).

Recent approaches to accessibility planning in the UK have sought to close this gap by:

- Making accessibility audits a core function of local transport planning (DfT 2004). These plans define how transport is integrated with other policies to deliver better access for all people and all trip purposes.
- Segmenting the population to recognise accessibility varies significantly between different mobility groups. For each trip purpose, the groups of people most likely to face exclusion on grounds of accessibility are considered.
- Introducing accessibility audit requirements to transport appraisal (Scottish Executive 2003) to ensure improvements in access for one group of travellers are packaged with measures to mitigate negative accessibility impacts on others (eg a new road might improve accessibility by car but can also sever communities requiring new pedestrian facilities).

New Zealand has recently developed guidance for undertaking integrated transport assessments (Abley et al 2010) and introduced the concept for undertaking accessibility audit requirements to transport appraisals. As noted above though, the greatest challenge for these accessibility audits is the impracticality of considering many hundreds of potential combinations of people groups, trip purposes and travel options in every assessment. Successful audits therefore require a high degree of skill by the auditor to target analysis and ask the right questions. Experience shows these are not strong skills within the transport sector, so some prescription is needed to ensure useful outcomes.

However, prescription within accessibility audit processes can potentially distort the aims of accessibility planning to ensure the needs of all people are met. Successful policies provide clarity on complex issues such as:

- The need to package investment to ensure balance and equity in programme delivery raises questions about the scope and geographical level for the audits. It is not possible for every group to benefit from every change, but overall it is reasonable to expect the needs of all groups are considered and reasonable action is taken to mitigate adverse consequences of change.
- The priority given to accessibility within different local neighbourhoods will vary. Rural dwellers choose to sacrifice accessibility for other benefits of rural life but in all neighbourhoods the greatest problems arise from unplanned or unexpected changes. For example, pressures within healthcare to provide specialised services at centralised locations often mean local centres will close. This can

create accessibility problems for low-mobility groups. A neighbourhood accessibility planning process needs to foster cross-sector cooperation to ensure consistency and equity at local, regional and national levels.

- At a project level, the needs of minority groups are only understood if detailed accessibility audits are undertaken (Litman 2012; Scottish Executive 2003) but an alternative easier goal achieves balance at a more strategic policy or programme level (DfT 2004).
- Seeking to resolve issues about winners and losers at a project level can make the packaging of transport delivery very complex, and lead to poorer value programme delivery (small amounts of landscaping, shelters, road markings etc are disproportionately expensive). However, if equitable solutions are not delivered at a scheme level then it can be difficult to guarantee the parallel investment will take place at the same time.
- Accountability and funding are managed within narrower boundaries than accessibility. Results of accessibility audits can therefore be more of a problem than an opportunity, unless the working partnership arrangements are in place to deliver multi-disciplinary solutions. In most countries, narrow high-level accountability means national or regional partnership structures have proved elusive. However, community and neighbourhood planning has proved to be a much more practical level to deliver partnership solutions.

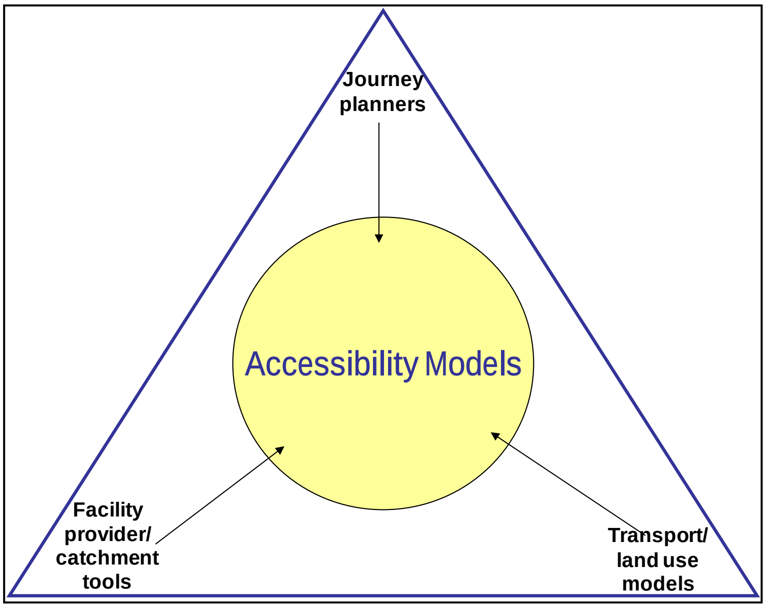
Where top-down policies foster and support bottom-up action then accessibility planning can thrive. The UK approaches have moved some way towards this but experience is growing internationally and current practice has substantial room for improvement.

4 Modelling approaches

4.1 Types of model

The tools typically available internationally for modelling accessibility fall into three categories as shown in figure 4.1.

Figure 4.1 Types of accessibility model



The models used by facility providers such as retailers and public transport operators generally start from the analysis of the local population and output information on the potential client mix within the local catchment. This allows providers to plan appropriately for the people able to access their services.

Some models have been derived from road or public transport journey planners and tend to be restricted to an analysis of the time it takes to reach different destinations.

Although transport and land use models tend to be much more complex than the journey planners or catchment tools they do not necessarily provide better information for accessibility planning unless linked with other models. These network and transport system models tend to have very few user groups. It is therefore necessary to use travel time information from these and link them with separate accessibility models to generate high-quality accessibility measures.

Due to the different functionalities of the different types of accessibility model available there is confusion about what an accessibility model comprises.

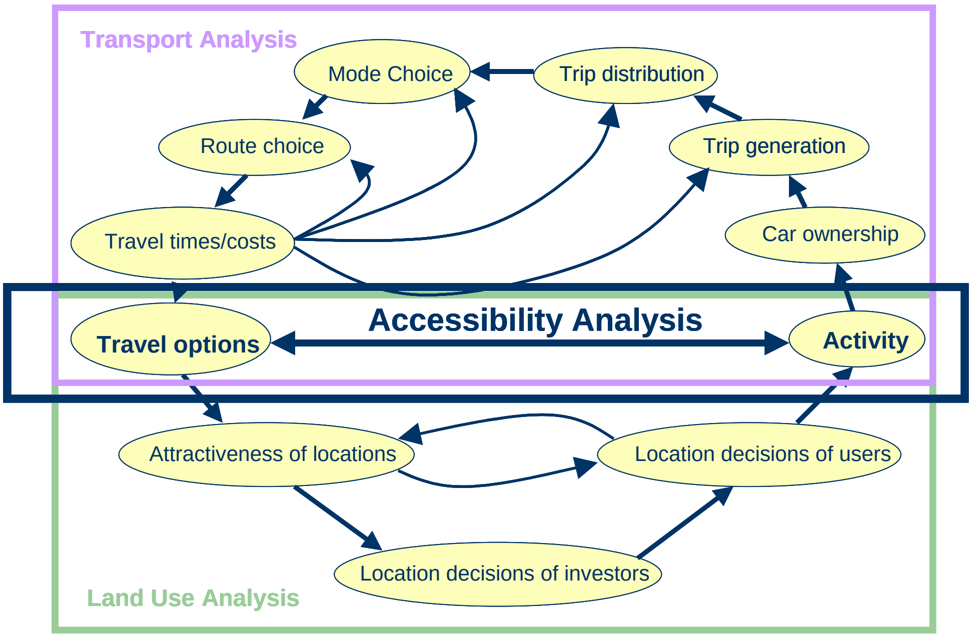
Instead, it is more useful to specify what indicators are needed and then identify what tools can be automated to calculate these. The standard functionality available in current databases and geographic information systems (GIS) is usually more than sufficient for most modelling applications, and by adding simple programming or macros to these, the repetitive indicator calculation can be automated.

There is generally very little transferability of models between areas. Most local authorities in countries with well-developed accessibility planning approaches have automated calculation procedures to meet their needs and in some places these have been 'branded'. These brands have been important to give the models credibility within an industry that has been traditionally heavily dependent on sophisticated models.

4.2 Model functionality

At its simplest level, calculating accessibility measures requires only some travel time data and some land use data so the two can be linked to calculate an integrated accessibility measure as shown in figure 4.2. Alternatively the accessibility analysis can be connected to highly sophisticated land use and transport analysis and forecasting models.

Figure 4.2 Classic stages in transport modelling



To illustrate the functionality of existing demand models, table 4.1 compares the capabilities of a selection of these models in terms of:

- transport analysis – the functionality that allows journey times and costs to be calculated
- land use analysis – the way location choice and land use affect travel including feedback loops from transport to land use
- the ability of different groups of people to access particular activities.

The selection of models seeks to illustrate the range of features available in existing software products.

Table 4.1 Examples of demand models with accessibility indicator functions

Model	Estimation of travel time and cost	Land use interaction	Accessibility indicator calculation and output
Transport demand models			
OmniTRANS (Omnitrans International – Netherlands)	Outputs average times by all modes and real-time simulations for traffic, but not clock-time public transport options. Costs estimated from distance.	Database functionality allows accessibility impacts of land use scenarios to be compared.	Optimised to compare access for different people groups using Cube functions and mapping interfaces.
Visual-TM (Peter Davidson Consultancy, UK)	Outputs average times for trips by all modes. Costs estimated from distance.	Land use as an input but not interactive.	Use of map-point GIS software provides a visual interface and data management for comparing impacts on different groups of people.
Cube (Citilabs, UK)	Outputs average times by all modes and real-time simulations for traffic, but not clock-time public transport options. Costs estimated from distance.	Land use as an input but not interactive.	ArcGIS interface provides mapping options for indicators.

Although these demand models have fairly sophisticated accessibility indicator and mapping functions there are many potential users of accessibility analysis who are unable to justify the large expense of a demand model. As a result, markets have developed for a larger and more diverse group of tools to analyse other influences on accessibility. A selection of these is described in table 4.2.

The demand models rely on public transport frequencies and estimated travel times by time of day but the majority of models in table 4.2 use actual service schedules and output accessibility results for a specified time of day and day of the week.

Table 4.2 Examples of models with accessibility indicator functions but no demand modelling capability

Model	Estimation of travel time and cost	Accessibility indicator calculation and output
Destinations are specified by model users rather than being considered as trip attractors		
Accession (Citilabs, UK)	Calculates journey times based on scheduled arrival and departure times.	Various contour and continuous functions are optimised for indicator and mapping outputs.
ICON (MCRIT, Spain)	Time and distance using average speeds using road networks.	GIS-based model to optimise regional accessibility indicator calculation.
AccessMAP – (CSIR Transportek, South Africa) the AccessMAP	Based on distance using GIS systems.	GIS based with indicators originally designed for planning new public facilities such as health centres but extended to investigate transport investment options.
ABRA (Colin Buchanan and Partners, UK)	Scheduled journey times from public transport timetables.	Spreadsheet based accessibility indicator calculation.
ACCALC (Scottish Executive, UK)	Travel times and costs not calculated but taken as outputs from transport models.	Functions to assist users to specify and output indicators for analysis and mapping.

Model	Estimation of travel time and cost	Accessibility indicator calculation and output
Destinations are specified by model users rather than being considered as trip attractors		
Capital – 'Calculator for public transport accessibility in London' (TfL, UK)	Public transport times from strategic public transport model for London and walking times estimated using GIS from distance from origin to the nearest modelled node.	Links to London's planning and development GIS for indicator calculation and output.
PTAM (West Yorkshire Passenger Transport Executive, UK)	A hierarchy of public transport nodes is determined and walk times to these from small local areas are calculated.	Travel time for users to services.
AutoPTpath	Highly optimised routing algorithms to be able to calculate optimal journey times for very large numbers of zones. Uses scheduled departure and arrival times for public transport.	Links to GIS for mapping.
WALC (University of Westminster, UK)	ArcGIS based with travel times for walkers being estimated and weighted based on obstacles faced (eg including steep hills).	Population catchment indicators are output based on a set of destinations.
Amelia (UCL, UK)	GIS used to allow user defined attributes to be allocated to links in the network to calculate travel times.	User consultations and focus groups being used to define parameters for indicators.

All the models in tables 4.1 and 4.2 include three main components:

- a relational database
- a GIS system
- some bespoke programming or macros to optimise functionality for a perceived market or planning need.

The balance between the above components varies. The demand models rely more heavily on bespoke programming. In some of the simpler models, the database functionality within proprietary GIS packages has been sufficient to allow the first two elements to be combined. However, for more substantial applications a separate database is required.

Accessibility models can involve very large travel-time matrices in order to provide spatially detailed zoning systems. File size limits in the software restrict the capabilities of most of these models. For example the Citilabs Accession model can cope with about 2 million OD pairs (ie about 1400 zones when mapping access to other people).

Travel time is considered in some detail within most of the models. Cost is also sometimes included but most models use simple distance-based proxies rather than actual fares for the group being considered. Other deterrents on travel are largely ignored. Models such as Capital, PTAM, WALC, Amelia and ACCALC allow other deterrents to be included within the analysis (eg to exclude links without street lighting from trips at certain times of day).

When considering neighbourhood accessibility the non-time factors can be particularly important so it is worth considering the relevant parameters in more detail.

4.3 Potential capabilities

Rather than looking at model 'packages', an alternative way of looking at model functionality is to consider all of the elements currently included in any model. Then by selecting the functions that are of most value to accessibility in New Zealand a model design can be established which is both practical and optimised to local needs.

Accessibility indicators assess whether any user or group of users can reach any destination or set of destinations. The capabilities therefore relate to three main components:

- The level of detail with which the user groups can be identified and their capabilities, eg how far they can/will walk.
- The types of destinations to which people are travelling and the way quality and choice are perceived by each group.
- The means by which each group of people reaches each set of destinations.

The first two of these are constrained largely by data availability as discussed in chapter 3. However, model capabilities also affect the ability to represent travel options. Based on an analysis of functions of a journey, table 4.3 shows the capabilities of different types of model.

Table 4.3 Capabilities of accessibility models

Functions of a journey	Accessibility models with a demand modelling capability	Accessibility models without a demand modelling capability
Opportunities and activities at the destination	Often included in add-in modules	Increasingly assisted data import facilities for a wide range of data sets
Travel time calculation	Times between centroids of zones with zone connector times being calculated from the area of the zone.	Times between either points or centroids of zones
Scheduling, eg target departure or arrival time or both, arrive before, depart after, departure or arrival during a specified period	No	Yes – specified by user
Travel cost and fares taking account of travel cards and concessions, fares restricted by quota, season ticket options and time-of-day restrictions	General and broad assumptions rather than actual ticket costs	Data problems
Interchange points by facilities available, eg shelter, information, staffed/porters, availability of luggage trolleys, CCTV	No	No
Interchange option, eg minimum time accepted for interchange, restrict interchange options between modes or operators, restrict the number of interchanges acceptable, availability of guaranteed connections	Can sometimes be specified	Can generally be specified
Route choice: minimum time, minimum cost, least amount of walking, include or exclude modes, avoid a location, route via a location or locations, etc	Route and mode choice usually based on generalised cost so average values of time can reduce accuracy for some groups.	Route and mode choice generally minimum time path

Functions of a journey	**Accessibility models with a demand modelling capability**	**Accessibility models without a demand modelling capability**
Mode choice, bus, rail, ferry, air, bespoke services (school transport, patient transport)	However minimum time routing often possible. Limited trip chaining allowed	
Day of the week, seasonal variations	Not explicit unless user seeks information	User specified
Real time updates and reliability, eg congestion, roadworks, delays	No	No
Health information, eg calories used	Occasionally	Occasionally
Environmental information, eg emissions associated with the journey		
Confidence building information, eg to confirm the validity of the results with map-based presentation, emergency telephone numbers in the event of problems	Yes	Yes
Type of vehicle, eg low floor bus, luggage carrying capability	No	No

The most comprehensive approach to an accessibility audit is to examine all the factors that affect an individual's ability to travel. However, in practice the simple accessibility analysis tools provide a broad sift which can be used in conjunction with the transport and land use models to add greater detail. To check the results for elements of accessibility not considered in these models, some sample audits can be undertaken. This is often achieved through consultation with end users.

5 A practical approach for New Zealand

Improving access to local services is inclusive, efficient and has many wider benefits for sustainable community development. However markets operate within narrower contexts than social need, so these wider benefits are often not reflected in the way services and destinations are provided. This chapter explains how accessibility measures could be used to help secure wider benefits, including more sustainable and inclusive communities.

Each person and organisation has different preferences and goals. Improving accessibility beyond the lowest common denominator relies upon raising the common understanding of what an attractive neighbourhood might comprise and the sort of solutions which can be delivered to foster:

- an inclusive society
- more active travel
- local economies of scale through working partnerships.

In chapter 3 it was shown the following is required:

- stated views of accessibility (which form the base on which to build)
- social indicators quantifying as far as possible the accessibility opportunities available
- comparative measures showing the extent to which the neighbourhood caters for the interests of all groups.

5.1 Accessibility planning methods

NZ Transport Agency research report 363 'Accessibility planning methods' (Chapman and Weir 2008) investigates the applicability of accessibility planning in New Zealand as a tool for assessing and improving personal access to essential services for all New Zealanders.

The report defines 'accessibility planning' as:

> *a structured process for the assessment of, and planning for, accessibility. It uses quantitative and qualitative data and employs tools such as geographical information systems to systematically assess a range of accessibility related information, including origins, the location and delivery of key activities and the transport links to and from them, and assist in the development of a set of accessibility indicators. This enables actual accessibility to be assessed against the indicators, which in turn allows accessibility problems to be identified, addressed and monitored. When fully developed the process is a continuous one and provides evidence of changes in accessibility over time.*

The key elements are that the focus is on opportunities for people and places and that the inherently cross-sectoral view of the world which people take is built into measurement, management and delivery of improvements. In the UK the accessibility planning guidance refers to the two pillars of the planning process being evidence about people and partnerships for delivery.

Chapman and Weir (2008) set out three existing international accessibility methods, which are comprehensive, limited and which regulate planning methods. Section 5 of the Chapman and Weir (2008) report summarises the status of accessibility planning in New Zealand against the seven criteria that are important in accessibility planning as shown in table 5.1.

Table 5.1 Accessibility planning in New Zealand

Criteria	Comprehensive planning	Current New Zealand status
Organisational responsibility	Multiple levels of government	Unclear – aspects of accessibility planning at all levels of government
Influence at local level	Significant	Unclear – some influence on RLTS and LTCCP development (mainly monitoring)
Assessment frequency	Continuous	Variable – generally in conjunction with RLTS and LTCCP production
Spatial focus	All areas	Mainly urban
Modal focus	Wide	Unclear
Use of indicators	Extensive	Variable – partial
Influence on project evaluation	Significant	Minor

Source: Chapman and Weir 2008

RLTS – regional land transport strategy

LTCCP – long-term council community plan

The report proposed an accessibility framework for New Zealand based on the comprehensive framework drawing from the same broad concept of accessibility employed in England. As shown in table 5.2 there are many potential drivers for accessibility planning and the relative importance of each varies depending on local circumstances. The report recommended the implementation of a comprehensive accessibility planning framework across New Zealand to increase collaboration between the traditionally disparate disciplines of transport planning, land use planning and social services.

Table 5.2 Proposed comprehensive accessibility planning in New Zealand

Criteria	New Zealand
Driver	Affordable and reliable community access
Spatial focus	Urban and rural areas
Organisational responsibility	Regionally led local application National guidance, priorities and monitoring
Used for transport plan development	Yes – regional land transport strategies and programmes
Assessment	Formal: In line with GPS; RLTS; RLTP and LTCCP development Informal: continuous
Process	Five-stage assessment using indicators and stakeholder input
Indicators of accessibility	A range of standardised national 'core' indicators Regional indicators supplement these as required
People focus	Education, work, medical and food shopping
Modal focus	Car, public transport, cycle and walking
Used for projects	Yes, for RLTP projects Potentially used as part of the resource consent process

Source: Chapman and Weir (2008)

5.2 Possible indicators

Prior to investigating how indicators might be delivered in New Zealand, the indicators highlighted in earlier research (Chapman and Weir 2008) provide a starting point for discussion.

Comments on international experience with such indicators is summarised in table 5.3. It can be seen that although many of these indicators have been used successfully elsewhere, there are significant limitations since they do not directly describe the opportunities available for different users to access services. It is therefore preferable that any new accessibility measurement should build up locally relevant indicators based on available data as described in the remainder of this chapter.

Table 5.3 Review of indicators previously proposed and employed

Indicator	Type of indicator	Successful examples and experiences
Access to private motor vehicles	A measure of mobility which identifies the people who are most likely to suffer accessibility problems	Many examples throughout the world allow accessibility improvements to be targeted where there is low car ownership. However, it does not help identify what improvements need to be made.
Access to public transport	An indication of network coverage, particularly where the services being accessed are categorised by frequency and destination type	The public transport accessibility levels (PTAL) methodology (see chapter 9) developed in London works well in a very densely populated area with frequent public transport and a large choice of destinations for each trip purpose. However, it can be misleading outside urban areas. Access to public transport can also be as complex to calculate as integrated accessibility measures so is losing favour relative to indicators which measure access using public transport.
Activity by cycling and walking	A measure of expressed accessibility	Generally a good proxy indicator of the health of a neighbourhood and widely used internationally. However, it does not help identify what improvements need to be made.
Transport behaviour	A measure of expressed accessibility	In a highly segmented analysis travel demand is a good indication of accessibility, ie if many low-mobility people are travelling to the shops then there is likely to be good access. This type of measure is widely used internationally. However, it does not help to identify what improvements need to be made.
Satisfaction with transport options	A measure of stated accessibility	This is an essential type of measure whether or not other quantified measures are used. In all parts of the world local people understand their accessibility problems.
Aspects of infrastructure such as the proportion of public transport fleet with enhanced access features	A transport accessibility measure	These are widely used to describe the product offered by transport providers. However, such measures do not directly indicate whether anybody benefits from the features or what people can access using the infrastructure.
Travel expenditure such as proportion of income spent on travel	A social accessibility measure	This sort of indicator is very useful, but has not been widely used since there are few places in the world where data on personal expenditure can be obtained at a level useful for accessibility planning.

5.3 National policies

There are currently no core accessibility measures in New Zealand defined explicitly at a national level, but improving accessibility is implicit in many of the national projects, programmes and policies. Therefore although it is not yet clear what the current New Zealand accessibility policies are, the process of measuring the accessibility impacts of current approaches, could provide the foundations for future accessibility policy development. .

There are also current policies and performance measures which are already closely aligned with improving local accessibility including:

- increasing the amount of active travel
- creating safer neighbourhoods
- improving air quality by reducing traffic pollution.

These provide a clear policy context for improving access by non-motorised modes to the local services that attract the most frequent trips. If more of these trips are made by walking and cycling then the consequences of the improved local access will be the delivery of the national policies.

The public transport accessibility aims are less clear. Away from major urban centres in particular, difficult trade-offs need to be made in planning public transport networks including:

- There is a balance between network coverage and fares. Public transport networks all rely on some degree of cross subsidy between services by location and time of day. Higher frequencies to improve journey times need to be traded against the higher costs of provision.
- Good accessibility for higher mobility groups will generally involve longer walks to high-frequency core routes. However, people with lower mobility prefer services that come closer to the origin and destination of their trip. Public transport markets tend towards the latter type of service, due to the stability of demand from this group among other factors. Making mainstream provision available to all mobility groups can therefore reduce accessibility and the competitiveness of public transport for higher mobility groups. However, if core routes can be developed that help to grow public transport markets overall, then the revenue available for public transport increases and this can result in more and better services, thereby improving accessibility. These are complex issues where accessibility policy needs to be significantly developed to allow the components of access that are valued to be measured.
- There is a balance between providing door-to-door demand responsive services and fixed route provision. In rural areas, best value delivery of improved accessibility can often be achieved through supported taxi services/taxicard schemes and community transport development (Scottish Executive 2001b).

Public transport accessibility aims are not implicit in the current national policies in New Zealand. The accessibility planning process can be used to define the role of public transport more clearly so clear accessibility outcomes can then be measured (DHC and UoW 2003). In the meantime the modelling techniques should not make assumptions about what sort of public transport system is needed until policy has clarified the role of public transport in improving accessibility.

5.4 Trip purposes

Earlier research (Chapman and Weir 2008) suggested the following trip purposes might be useful for accessibility indicators in New Zealand:

- school education (separately for primary and secondary schooling)
- further education
- work (often measured as the choice of jobs available)
- hospital
- doctor or primary health organisation
- supermarket (urban) or food-oriented convenience store (rural)
- petrol station
- pharmacy
- bank/cash machine
- public transport.

This is a reasonably comprehensive list but for the purposes of neighbourhood accessibility the following could also be added:

- leisure centres and facilities
- sports facilities
- cinemas
- community centres/cultural and religious activities
- police stations/consumer protection agencies/legal advice
- population (as a proxy for friends and family).

5.5 Data sources

All indicators need to be based on readily available data and in each local area there may be rich data sources which are not available nationally. The toolkit for measuring accessibility should therefore have the flexibility to use a wide range of local sources while making use of nationally available datasets.

National data sources identified earlier (Chapman and Weir 2008) include:

- census
- Ministry of Transport's New Zealand Household Travel Survey
- Land Information New Zealand
- transport provider data
- regional council commuter surveys in major centres.

These are typical of the data sources in use in most countries but it is likely accessibility indicators and data collection would need to be developed in parallel to ensure relevant data was being collected to allow the accuracy and scope of the indicators to be enhanced. Key data includes:

Transport

- electronic timetable data
- electronic databases of fares
- location data for bus stops and rail stations referenced to the timetables and fares
- databases describing the attributes of the road, footpath and cycleway network by link

Activity and people

- census of population
- census of employment
- health, welfare and other indicators of population characteristics at a fine spatial scale
- locations of all land use activities to be included
- data allowing the quality and size of activity provision to be measured, eg floorspace, turnover, number of customers.

5.6 A typology of accessibility measures

In order to reflect the policies and available data the starting point for accessibility measures recognises that transport is a derived demand and both the supply of opportunities and the supply of transport need to be included for each population group.

Accessibility measures fall into three main categories:

1. Decisions about the local street environment – accessibility by walking and cycling to local facilities
2. Decisions about transport investment – accessibility of public transport systems
3. Cross-sector decisions about accessibility plan delivery – access to opportunities using road and transport systems.

There are many combinations of people, activities and links that define accessibility in any individual situation. A practical approach to accessibility measurement must assist the assessor to:

- define activities to represent quality, choice, scale, need, restrictions on availability, opening times, scheduling and other factors relating to the service provision
- segment the population to reflect abilities and perceptions, given these are often specific to individuals or small groups
- ensure a broad view of all transport and communication options, which reflect all aspects of modal choice, telecommunications, and quality in terms of speed, cost, prestige, security, comfort and other factors.

Where quantitative data is not available on any aspect, then the toolkit needs to utilise qualitative measures to ensure it can assist the user to make the best possible decisions. One of the greatest concerns with accessibility analysis and modelling is that it is very data hungry. Although data availability has increased very rapidly in recent years, accessibility analysis is still dominated by tools that consider mainly travel time and in some cases cost. Although it has been practical for many years to include a wider range of factors using existing data there remains a surprising lack of rigorous analysis of factors other than time and cost. Even large investments in information, ticketing, Wi-Fi, CCTV and other factors have taken place with very little analysis of priorities despite practical accessibility analysis approaches being available.

The earlier parameters can be used within the toolkit to assist users in selecting and inputting the best available data set or prompting for the collection of data where there is none available. The outputs can then ensure accessibility planners tackle all of the critical barriers to access and provide relevant information to support fund assembly and project delivery.

5.7 Reporting accessibility findings

The breadth and flexibility of accessibility analysis opportunities are both an opportunity and a threat. Providing useful, relevant indicators and results is a powerful way to support the delivery of improvements and working partnerships. However, it is very easy to output vast quantities of data which can cause more confusion than benefit.

The user interface therefore needs to help define what information about accessibility, or the potential to change accessibility, will be most useful. The design of the interface should be informed by policy requirements but is likely to include at least the following capabilities:

Community or social outcomes

- The choice of opportunities available for shopping
- The travel time and cost to the nearest opportunity
- Information about the catchment population able to access shops, health centres and other local facilities using active travel modes
- The catchment population able to access shops, health centres and other local facilities using non-car modes including public transport.

Comparative measures

- The ratio of travel times by different modes to assess the potential for modal shift
- Accessibility for low-mobility groups compared with higher-mobility groups, eg non-car/car, mobility impaired/fully mobile.

Stated perceptions

- Perceived barriers to reaching neighbourhood services
- Cultural factors affecting travel choices, eg car dependence
- Levels of knowledge of travel choices available.

6 Part 1 conclusions

Accessibility assessments have the potential to guide policy makers to deliver improved accessibility in New Zealand both by clarifying current implicit accessibility policy, and by setting out new explicit policies. Without a practical delivery focus modelling can quickly become unmanageable since accessibility models are not helpful if solely data driven. It is by understanding the needs of people, businesses and places that the policy context becomes clear. Demonstrating the usefulness of accessibility planning in practice will ultimately provide the fuel to drive accessibility policy.

Accessibility indicators need to include expressed, social, stated and show comparative need. Different indicators will be practical at national and local levels. A national New Zealand approach could include defining a set of destinations for which accessibility measurements are needed and then calculate the travel time from each house address point to the nearest destination of that type using defined modes and combinations of modes.

Management and audit frameworks should be clarified to ensure the analysis requirements directly support the administrative structures.

To assist the development of an accessibility modelling toolkit, it should be possible for some of the functionality from existing models to be transferred to a New Zealand situation, eg mapping of outputs and editing networks.

However, the time-consuming part of accessibility modelling is the data assembly and management, and for this it will almost certainly be more efficient and practical to automate bespoke accessibility tools to help manage the available New Zealand data.

PART 2: NEW ZEALAND ACCESSIBILITY: PRACTICE AND RESOURCES

7 Introduction to Part 2

7.1 Why accessibility?

As cities grow and develop over time, changes take place that impact on the accessibility to various services and activities for the population living within and around the city. Land use changes such as the establishment of shopping mega-centres, which provide cheaper prices and a wider range of goods have precipitated the demise of the local store. But has access to opportunity and choice improved? These mega-centres provide a greater level (and range) of services, but there are less of them in a city and they are more sparsely located, yet local facilities often find they cannot compete and close. This increases travel distances for the majority of the population. The increased distances travelled may also result in transportation mode shifts, reducing accessibility and possibly magnifying inequalities for at-risk members of the community.

Urban sprawl typically increases the distances the population needs to travel and therefore increases travel times. Some cities have addressed urban sprawl through the provision of high-speed arterial roads and motorways, but this encourages a reliance on private motor vehicles and results in an increased dependence on oil, increased air pollution and other negative impacts. It also increases inequality in accessibility, as it does nothing to provide for sectors of the community that do not have access to a private motor vehicle. Another approach to containing urban sprawl is to enact polices to limit expansion of urban boundaries and increase population densities around key services. This reduces travel distances and can encourage modal shift towards more sustainable modes of transport such as walking, cycling and public transport. This can in turn reduce transportation congestion and pollution.

So which of these approaches does more to increase accessibility? In order to improve and measure the progress towards any goal, the first step is to be able to objectively measure what one is setting out to change.

7.2 Structure of Part 2

Chapter 8 outlines the background to development of an accessibility assessment tool for New Zealand and the role of accessibility in New Zealand policy.

Chapter 9 provides examples of accessibility planning concepts being applied to projects in New Zealand.

Chapter 10 discusses existing accessibility assessment tools including existing demand models, online journey planning provision, GIS and existing bespoke accessibility assessment tools such as Accession.

Chapter 11 provides conclusions to Part 2.

8 Developing accessibility measuring tools for New Zealand

8.1 Defining accessibility

Accessibility is concerned with both the land use and the transport system. As discussed in the introduction to this report, the exact definition of what is accessibility is elusive. A selection of definitions of accessibility from various studies, listed from earliest to latest, is:

> *Accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation.* (Hansen 1959)
>
> *...it is some generalised measure of ease of interaction.* (Harris 1966)
>
> *Accessibility denotes the ease with which any land use activity can be reached from a location using a particular transport system.* (Koenig 1980)
>
> *Accessibility is concerned with the opportunity that an individual has to partake of a particular activity or set of activities. It is not concerned with behaviour, but with the opportunity, or potential that people at a particular location have of interacting with different types of land use.* (Davidson and Pretty 1990)
>
> *Accessibility is a characteristic which can be possessed by both a point in space, or a region (i.e. it can be point specific or integral, the latter being a summary measure of the individual accessibilities of all points in a region); which can be considered at various levels of aggregation (e.g. accessibility to a particular activity or to all activities; by one mode or all modes); which may be measured in terms of a number of different attributes (i.e. time, money and other level of service characteristics such as comfort, frequency, safety etc.); and which is perceived differently by different individuals (for example, travel time is valued more highly by some people than by others).* (Peacock 1993)
>
> *...accessibility, or the ease with which locations of interest can be reached for desired interaction.* (Helling 1995)

Or put another way, and as deduced overall from Part 1, 'accessibility' is defined by the authors as:

> *The ease with which activities, either economic or social, can be reached or accessed by people.*

Therefore, accessibility assessment is the measurement of how easy it is for an individual to participate in desired activities, based on a set of measurable factors, including mode and destination choice.

Accessibility using transport systems includes three interrelated components: 'Capability', 'Opportunity' and 'Mobility':

1. 'Capability' represents the ability of people to use the transportation network, for example a bus with a low floor provides a capability for mobility-impaired people's ease of boarding and access to the public transport network. Similarly being licensed to drive and having access to a vehicle enables people to use the road network.
2. 'Opportunity' represents the availability of a land use activity or service, for example the presence of a supermarket provides an opportunity for shopping, and a school or college provides an opportunity for education.

3 'Mobility' represents the ease of moving through the various transportation networks, for example congestion on a highway often represents the level of mobility for vehicles. The amount of delay when crossing the street often represents the level of mobility for pedestrians. Terms such as 'level of service', 'average network speed' and 'vehicle operating capacities' are frequently used to describe mobility.

It is this last term 'mobility' that transportation professionals will be the most familiar with (especially from the perspective of motorised vehicles). A significant amount of study has been undertaken in this area and mobility continues to remain a major area of research. Unfortunately mobility is often the only way the quality of the transportation system can be measured as accessibility is generally ill-defined. As a result, the interaction between capability, opportunity and mobility is not well understood.

Accessibility depends on the relationship between these three components and is concerned with both the land use and the transport system. The achievement of accessibility is 'access' but access by itself doesn't describe the quality of choice or ease of being able to reach the destination. For example access to a medical practitioner could be achieved in a number of ways, such as walking to a bus stop, travelling to a rail station, waiting for a train, travelling on the train, alighting at the nearest station and travelling by taxi to the intended destination. It could also mean a house call by the medical practitioner. In both cases access is achieved, but clearly one provides a higher level of accessibility or ease by which the activity is reached. Accessibility provides an integrated way of measuring changes in either the land use or transport system. All practical approaches for New Zealand therefore include capability, opportunity and mobility as mentioned earlier.

8.2 Accessibility and transport modelling

All types of modelling are intended as an input to the decision-making process; accessibility modelling provides another input.

Accessibility indicators are central to most transport models. However the indicators are typically used within the model as part of the trip generation and distribution analyses. There are a number of reasons why the existing transport models do not meet the needs required of a potential new accessibility tool.

First, traditional transport models are designed to be most accurate for understanding the demand for travel, and demand is most important for motorised modes. This means the modelling of modes such as walking and cycling, for which demand is rarely a consideration (apart from crowded centres such as major railway stations), is rarely undertaken in detail.

Second, the representation of travel choices and behaviour is averaged down to a few dominant travel groups relevant to demand. However travel demand has many niche markets, not just people with poor mobility who have physical difficulties, but people with different levels of wealth, fitness, expectations and desires. For this reason it has been common for commercial transport operators not to rely on the transport demand models used in road planning, and instead to use accessibility models to understand the characteristics and needs of people in the catchments of bus stops and railway stations. This practice is also used by other commercial operators such as supermarket chains and major retailers who plan networks of stores using accessibility/catchment analysis.

In transport planning, accessibility models are therefore bridging the gap between the sophisticated demand models in current use by transport planners and the crude accessibility models used by market analysts. Figure 4.2 in Part 1 describes the traditional models in more detail. An accessibility modelling approach for New Zealand therefore starts from existing strengths but also recognised weaknesses, not met by either the market or transport demand models, including a lack of understanding of the following:

- How the needs of minority groups are met including physical, security, information, safety and other constraints on transport use.
- What opportunities for walk and cycle access are available since these modes are free at the point of use and capacity is seldom an issue.
- How forecasts of land use change affect travel. Although land use forecasts are used in current travel demand models there is limited analysis of the feedback loops. For example a retail impact assessment might show that a local grocer will close if a new supermarket opens but this level of detail is rarely included in land use transport interaction modelling.
- How modes of transport relate to each other. Models based on demand need to be calibrated based on supply/demand relationships but most trips are multi-modal and calibration of multi-modal trips is more complex.

The strengths of transport demand models are their mathematical modelling created to anticipate the required changes in the transport network when supply and demand changes. These types of models anticipate how many people 'would' choose a particular model of travel and consequently these types of models are most useful when identifying where to add capacity to roads, railways or bus systems.

However, assumptions in mathematical algorithms based on past trends are not so useful when looking at the sensitivity to factors not included in the calibration of supply and demand. Therefore it may be that power sockets and Wi-Fi on trains will lead to large increases in rail travel, but a demand model based on the calibration of systems where there is no data on power sockets or Wi-Fi gives little insight into the impacts. Additionally, the analysis of what people 'would' do does not recognise other travel options that may be only slightly less economically efficient or are currently not provided so are not possible to utilise.

Accessibility planning acknowledges the opportunity rather than just the ease of moving through the transport network. Modelling accessibility therefore considers what people 'could' do. Accessibility planning looks at how changes affect the opportunities for people. It is not always the case that better access capabilities result in more travel demand, but there is a close relationship between travel opportunities and travel demand.

In looking at the need for an accessibility modelling capability the key points are that there are policy sensitive issues not currently being modelled and a potential for new types of model to add value to and expand on the capabilities of existing analysis. Accessibility modelling can include all modes of transport since the focus is the traveller, not the modes they use. These models do not replace demand modelling but are complementary. Accessibility modelling is best used as a precursor to, or in development with, traditional modelling given a number of the initial inputs are the same.

8.3 Models relevant to New Zealand policy

'Improving access and mobility' is one of the five transport objectives of the Land Transport Management Act 2003.

The NZ Transport Agency's (2011) *Statement of Intent 2011–2014* includes a key long-term outcome for transport as 'an accessible and safe transport system that contributes positively to the nation's economic, social and environmental welfare'. One of the indicators for measuring progress for this outcome is 'more transport mode choice', especially in the area of public transport for work and study purposes. The statement of intent also states 'We are committed to: protecting and enhancing the natural, cultural and built environment, enhancing the quality of life for New Zealanders by improving community liveability…'

These high-level aims for improved accessibility need to be unpacked through analysis to understand the changes and investment that will deliver the top-level goals. Some of this is already being achieved through demand models, but accessibility analysis is needed to understand how people, places and business are affected by investment decisions. This should help to optimise investment plans to secure the nation's economic, social and environmental welfare.

Accessibility planning is generally undertaken at two levels. The higher level includes accessibility planning at a national or large spatial scale and tends to use zones of up to a few kilometres in diameter consistent with national or regionally significant transport demand models. The lower level has a much finer resolution representing the details of local neighbourhoods in cities, suburbs or regions. In Germany, and The Netherlands the higher-level assessments are undertaken by central government and the lower-level assessments are undertaken by regional or local government. The UK is unusual in that weak data availability within local authorities prompted the government to create a national model of accessibility to support the government's publication of detailed statistics covering local neighbourhoods. In the UK both travel demand and accessibility modelling is undertaken by some local authorities.

Accessibility planning is cross-sector from the perspective of policy and indicator development. Central government, local and regional councils and the private sector can all benefit from analysis relevant to their needs. Policy can be thought of as the 'should'; in other words, setting the direction between all possible options, and the specific direction or directions that are considered the most appropriate.

The role of accessibility assessments in the dimensions outlined above are illustrated in figures 8.1 and 8.2.

The private sector role in accessibility analysis has already been recognised. Retailers, developers and other private companies have been major users of road-based accessibility analysis for many years and tend to have the best data sets on the locations and services offered at each place. Understanding the socio-demographic characteristics of the catchments of a location is often critical to a commercial activity's viability. If public authorities work in partnership with private companies they can build on the existing analysis yet focus on policy sensitive user groups.

Figure 8.1 National and local accessibility assessments

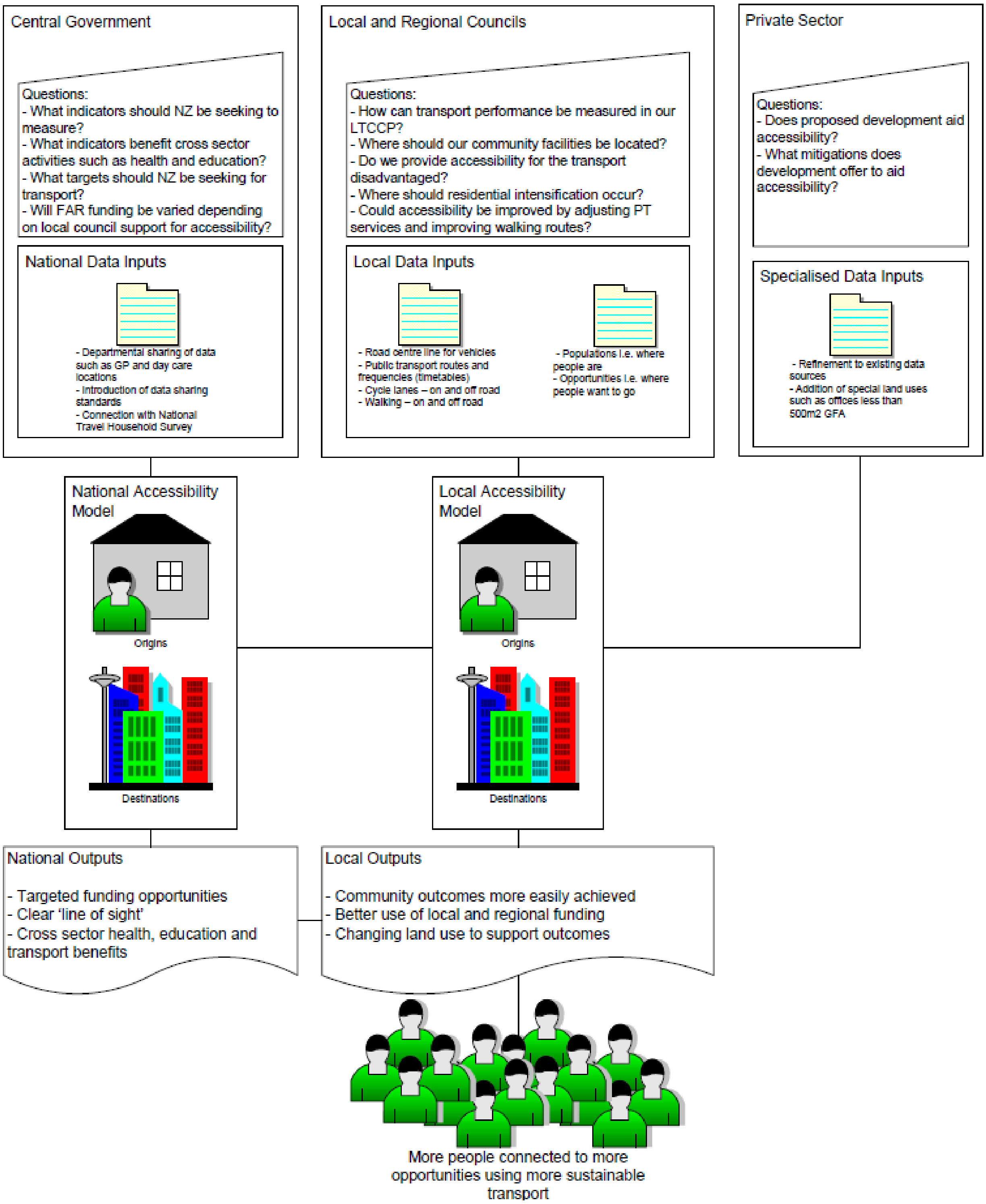
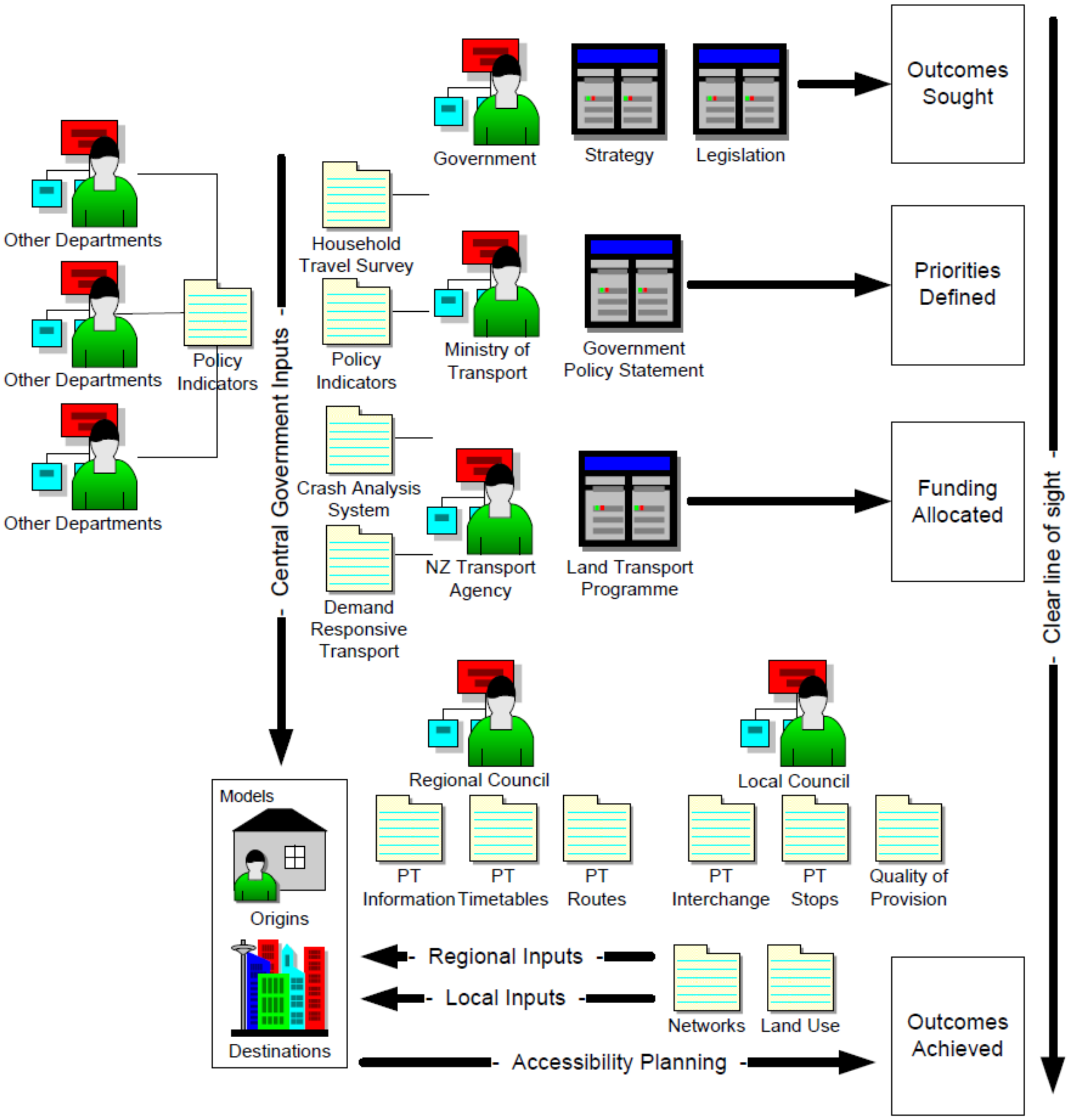


Figure 8.2 Levels of government achieving common outcomes



8.4 Indicators to meet the needs of New Zealand

Accessibility assessment requires appropriate core accessibility indicators. This makes the task both feasible and manageable at all levels of governance ranging from national policy to neighbourhood consultation.

Accessibility indicators are used to measure and make comparisons between the accessibility of particular locations to other locations. Although it is not the purpose of this research to develop accessibility indicators for New Zealand, the type of indicator to be measured guides the assessment tool required.

There are five key properties that accessibility indicators should possess. These include (adapted from Davidson 2009):

- Consistency – if there is no real change in the system, then the indicator should not change. If there is real change in the system then it should change.
- Ordinality – an improvement to the system should result in a change to the indicator in a particular direction. Further improvement should result in a greater change to the indicator in the same direction.
- Linearity – in order to be properly useful in looking at tradeoffs in projects, or knowing how much better one project is than another, the indicator must also be a linear measure. Linearity is required whenever indicators are to be combined.
- Meaningfulness – units should be a meaningful measure of the system being described. For example, $, min.
- Transferability – the indicator must be able to be moved from city to town and preferably rural areas as well and still remain relevant and comparable between locations.

The New Zealand Household Travel Survey (NZHTS) is a good starting point when looking to develop core accessibility indicators for New Zealand as it is an already established source of data that contains current information on individual travel patterns of New Zealanders. However, the survey cannot be used to identify where there are spatial opportunities for improvement, and it also cannot generally be used to forecast future travel patterns (Milne et al 2011).

8.4.1 Learning from elsewhere

In Part 1 the use of indicators that have been developed elsewhere was discussed. Chapman and Weir (2008) recommended the development of a comprehensive accessibility framework for New Zealand similar to what has been implemented in the UK.

The UK practice recognises that travel time is a necessary condition for access so national indicators based on travel time can identify gaps in transport systems, or in the location of facilities. Local authorities should also be able to identify other gaps because just having an achievable travel time is not the sole determinant (or condition) for access.

The UK national indicators were developed through extensive negotiations across sectors and between national and local government. This means the resulting indicators are a function of the process by which they were agreed. While no individual party would necessarily choose the indicators, it was an achievement to gain the agreement of such a wide range of organisations from health authorities to the national department of transport. However with 97 different indicators, each with multiple ways of representing travel time separation, resulting in 568 different indicators in total, the UK approach is inevitably a compromise. Ten years after the indicators were first put forward, only a few are being used. In 2010 the indicators were also renamed 'accessibility statistics' to clarify that they were a resource for use nationally and locally to help with accessibility planning, rather than an indicator of performance for any individual organisation.

It is of note that there has been an unhelpful debate between central and local government about thresholds. Central government was careful not to set travel time thresholds due to concern the thresholds could become a target. National government used continuous indicators for monitoring for five years but the Hansen style indicators were poorly understood. With a change of government in 2010 leading to greater autonomy for local government, the monitoring of local government largely ceased including monitoring accessibility. The national accessibility indicators are therefore published as a resource to assist with accessibility planning.

Across England, Scotland and Wales the only indicators in common are travel time to health, education and shops. These have been widely used for comparisons across the UK, including by campaigning groups, and are widely regarded as being the most established indicators. These indicators have the advantage of being both easy to understand and robust. For example, most people can understand a statistic for each house address that shows the total time it takes to walk to a grocer, school and GP, or the total public transport travel time to reach a major hospital, further education and a regional shopping centre. When looking at the competitiveness of modes, the ratios of these travel times have been most useful and the UK planning policy guidance recommends that ratios of car to public transport travel times are reported for all new developments.

One of the first decisions needed in New Zealand will be how wide a consensus is needed on the choice of indicators. For example, if the NZ Transport Agency (NZTA) sets indicators for access to employment without consulting other agencies, these agencies may see the chosen indicators as irrelevant or may oppose them. In the UK, access to health and education are statutory responsibilities of the health and education departments so if transport agencies set targets for these without first consulting the other groups then there could be complex consequences.

New Zealand local authorities may also have significant differences of opinion as was observed in the UK, and, for example, prefer indicators that better suit New Zealand's rural character in some regions.

The UK national core indicators provide a useful snapshot of travel times. The primary focus is on destination access for two main reasons (DfT 2008):

1. The calculation is easier when it requires only the nearest destination of any particular land use type.
2. The indicators clearly differentiate the characteristics of the catchment population allowing opportunities for socially excluded population groups to be compared with the total population.

In the UK it has been particularly difficult to gain consensus on the origin indicators. How much retail floor space is available or the number of jobs accessible from each origin were initially published but the indicators proved to be too sensitive to variability in data quality. Over time the indicators have been allocated to broad bands representing the level of choice, but further work is needed to calibrate perceptions of choice with measured opportunities.

All countries using accessibility indicators change the indicators used in monitoring regularly so the lesson for New Zealand seems to be to maintain a flexible approach and use relevant indicators for each policy need. Common pitfalls from the UK analysis (DfT 2008) are reported as:

- The indicators are poorly understood and used.
- Each indicator should be optimised for planning and other needs.
- There are currently too many indicators for the purpose of monitoring.
- Further work is required to determine the strength and weaknesses of each indicator at their respective national, regional and local implementation level.
- The chosen thresholds should relate to policy, monitoring or behavioural criteria, for example:
    - if monitoring then the lower threshold should relate to about a third of the population
    - if monitoring then the upper threshold should relate to about two thirds of the population
    - behavioural thresholds should relate to the population being considered – for example, NZHTS data should be applied in New Zealand
    - policy thresholds need to be developed with other government agencies – in New Zealand this would include targets developed with the Ministry of Education, Ministry of Health etc

- Where data quality is high the indicator quality is also high, and conversely poor data quality leads to low indicator quality.
- Car accessibility should be included in the accessibility calculation because it would be helpful for non-transport stakeholders to understand relative provision between modes and destination choices.
- Ratios of accessibility of car and non-car modes would be useful to show locations where there are gaps in public transport/cycling and walking provision.

All of these issues will be important in designing a suitable indicator set for New Zealand.

9 Applications within New Zealand

9.1 Introduction

Abley Transportation Consultants (Abley) has undertaken a number of accessibility assessments and it is useful to describe some of these because they originated from New Zealand practitioners seeking solutions that were a little different from the norm. The following sections of this chapter outline four basic examples. These examples provide samples of the application of accessibility assessment in New Zealand and are listed in increasing complexity and sophistication.

9.2 Suburban public transport interchanges

A methodology for prioritising possible suburban public transport interchange locations was developed prior to the devastating Canterbury earthquakes of September 2010 and February 2011. A number of measures were included to inform the implementation priority of suburban interchange sites throughout Christchurch.

One measure was based on the potential coverage area for passengers travelling through any interchange site in the peak period from 3pm – 6pm. The method took account of the number of bus services and frequency at each site and calculated travel coverage area over a fixed period of 20 minutes, which included waiting time. The measure assumed a person arrived at an interchange without knowledge of the bus timetable. Waiting time was calculated based on the average person typically waiting for half the service frequency (ie some people arrive just before the bus leaves, others just miss the bus). The speed of travel on the road network was set to the Environment Canterbury (ECAN) target of 26km/h for travel on bus services in peak periods.

Locations such as Westfield Riccarton and Christchurch Public Hospital scored highly on this measure. Suburban shopping centres such as the Palms, Bush Inn Centre and New Brighton were the next highest rated on this measure but these were rated considerably lower than the first two sites. Christchurch airport, Princess Margaret Hospital, and suburbs such as Lyttelton, Bishopdale and St Martins scored poorly against this measure.

The measure, although not strictly an accessibility assessment (ie measuring 'opportunity'), did make use of a number of the elements that would inform an accessibility assessment including walking and public transport networks, bus-stop locations and service frequencies.

9.3 Residential intensification

The mobility of users on foot from key locations to certain land uses in 5-minute and 10-minute bands was determined for Christchurch. This is an example of a simplistic step-wise indicator applied to walking. The land uses included:

- regional centres
- district centres
- supermarkets/supermarket-based centres (if different from district centres)
- suburban public transport interchanges
- bus stops on high priority public transport routes and the Orbiter and Metrostar routes

- high-amenity open spaces/recreation facilities such as Hagley Park
- destination parks such as Halswell Domain, Barrington Park, and Burnside Park
- primary schools
- libraries
- primary health-care facilities (GPs).

The intent of this study was to identify areas that are well supported in terms of walking facilities. The results enabled locations to be prioritised and informed the assessment of locations where residential development could be intensified. The assessment could have been extended to a composite style indicator allowing each key location to be easily compared against other locations.

9.4 Public transport accessibility levels (PTAL)

The study aimed to find out how well different commercial centres in Christchurch were served by public transport. The public transport accessibility levels (PTAL) methodology developed by the London Borough of Hammersmith and Fulham in 1992 (TfL 2010) was used to inform this assessment.

A detailed city-wide walking network was developed using Environmental Systems Research Institute (ESRI) ArcGIS. The walking network included various time-based deterrence functions to a maximum walking time limit or equivalent walking distance. The time-based deterrence functions included delays for road crossings based on crossing type, traffic volumes and road hierarchy. This was a significant advancement on the 'as the crow flies' distance buffer that is often used. Factors on the network such as delays at road crossings and urban design factors significantly affect straight line maximum walking distances.

A computer model was developed using Python and ESRI ArcGIS to automate the analysis. The model was run on all district centres and business retail parks. A grid consisting of a point of interest every 100m over the Christchurch urban area was created and PTAL calculated for more than 19,000 grid points. The model was validated against a number of manual calculations.

Although PTAL indicators are controversial in the UK, being described as lacking in a credible theoretical foundation and certainly only suitable for analysis of dense urban areas such as in London, performing the detailed PTAL analysis resulted in some interesting and insightful outcomes regarding the pattern of public transport accessibility in Christchurch. The accessibility index (AI) value calculated for each point of interest was categorised into one of eight PTAL bands. It was found that applying London PTAL bands to Christchurch AI values resulted in what appeared to be an unfair representation of Christchurch public transport accessibility. Consequently new PTAL bands were generated specific to Christchurch that provided a fairer representation for this community based on existing performance.

PTAL only measures access to public transport and is not a true accessibility assessment as it does not include demand for the specific public transport routes and interchange options provided at the point of interest. Nevertheless, the PTAL analysis undertaken for Christchurch was useful to describe to practitioners where enclaves of poor public transport accessibility might exist. It also proved useful to demonstrate that existing measures, such as access to a bus stop within so many metres, could be improved upon.

9.5 Long-term council community plan (regional)

Given what was learnt from the PTAL assessment, new indicators for how well public transport was supplied were considered useful. These new measures were expected to provide a clear line of sight between the management and the measurement of public transport.

The current indicator relating to public transport was:

> *Percentage of the urban population in Greater Christchurch and Timaru within 400m of a bus route.*

Problems with the above indicator included the following:

- The 400m was measured as the 'crow flies' and therefore did not reflect the fine-grained nature of walking networks.
- The indicator only measured access to bus routes, whereas in reality access to the public transport network could only be made at the bus stops.
- The indicator did not take into account the frequency of bus services or where the bus was going to.

Therefore, the current indicator was less than ideal.

An updated indicator was developed that included the percentage of households:

- in Greater Christchurch and Timaru within 500m walking distance of a bus route
- in urban Greater Christchurch with access to two or more key activity centres by public passenger transport services within 30 minutes total travel time.

The first measure has remained a mobility measurement. The second is a true access measure and quantifies the opportunity provided by the public transport network both in terms of network supply and a basic geodemographic measure.

9.6 Discussion

Measures of access to public transport such as PTAL should take account of what destinations can be reached via the local public transport node. Having access to a local bus stop is of little practical use for regular shopping if there is only one bus a week. The analysis of coverage of major public transport interchanges and of residential intensification is therefore much more useful for describing accessibility as a resident of a location would observe or understand it.

However all of these practical examples are much simpler than the theoretical concepts discussed earlier in this report and the applications in use in some countries. For example the basic examples above do not assess:

- cumulative opportunities
- all transport modes
- complex geodemographic factors
- continuous indicators.

However, although the basic examples above do not include all aspects of accessibility, they identify there is a latent demand within the transport planning community for considering transport from a non-traditional basis.

10 Accessibility assessment tools used in New Zealand

10.1 Introduction

Some accessibility assessments are undertaken implicitly within existing transport models. However, in recent years there has been recognition these models omit some important elements of accessibility and accessibility planning should be more comprehensive and systematic.

This chapter discusses the advantages and disadvantages of different model forms that are available to measure accessibility.

10.2 Existing transport demand models

Traditional transport models have focused on travel demand, yet demand is rarely a major influence on walking and cycling access. Demand has the greatest impact on accessibility by car so, maybe unsurprisingly, currently it is car accessibility (or mobility) that is modelled in most detail.

Many transport models have not kept pace with current technology. Automated data feeds from electronic public transport journey planners have yet to be incorporated into many software products. Until about 2005 this left a gap in the market for software that could read in the various journey planning file types and represent public transport travel times geographically.

Traditionally, demand model segmentation of the population did not reflect the fact that access for some travellers was of greater policy importance than for others. Analytical skills were poorly developed in drilling down within transport model results to look at target groups of people and access for particular trip purposes.

Cost and time have generally been the focus of most analysis, and other barriers such as access to information, physical access, safety, security and level of comfort have not generally been modelled.

For these reasons, modelling tools available internationally are undergoing further development. Some of the improvements include:

- Pedestrian demand models (previously only used in congested locations such as entrances to stations) are being developed to be able to read in digital maps and map access by walking.
- Tools to read in data from public transport journey planners are evolving, with the worldwide Google Transit project being the largest software development in this field.
- Various local software tools have been developed to help segment travel markets and calculate accessibility indicators relevant to local policy needs.

However, these represent only a few of the gaps in traditional transport modelling. A New Zealand accessibility assessment tool has the potential to close all of the gaps by guiding users through all the steps including ‘Will the person at this address have the necessary information?’ to ‘Have they the physical capabilities to travel to the bus and board it?’, ‘Is this a safe route?’ when linked with other tools, eg community street reviews (Abley 2010), and many other similar questions.

10.3 Journey planning

Journey planning is a form of accessibility model. The core output from journey planning software is the total cost of a journey from one point to another. This is also the primary measure of accessibility. The cost may be measured by time, economic implications, or by any other preferred measure. As journey planning tools already operate in New Zealand, it is important to consider them as a type of accessibility assessment model. Their suitability as an adaptable tool that could be used to assess accessibility in New Zealand should be considered.

Website journey planning typically includes the steps outlined below. Journey planning services available in New Zealand generally follow these steps, with slight variations:

1. A user enters their desired origin and destination (OD) for the journey in the format of a street address or a well-known landmark.
2. The journey planning software attempts to interpret the user's locations and then returns a list of possible addresses and landmarks for OD locations. At this stage the user confirms their desired locations from the lists created by the software. The user also enters their journey preference, be it by optimising time, cost or avoiding certain vehicle types or locations.
3. The software returns to the user a summary of possible journeys the user can take to reach their destination. These journeys include summaries of time taken, distance travelled, transport modes and total cost of the journey.
4. The user selects their preferred journey and is able to view it in more detail. The detailed journey often includes maps, route numbers and estimated departure and arrival times. The user then has the option of printing or saving the journey.

A review of New Zealand journey planning tools was undertaken in 2008. At that time only three organisations in New Zealand were running web-based journey planning services including Auckland Regional Transport Authority (ARTA)[5], Greater Wellington Regional Council (GWRC) and Environment Canterbury (ECAN). Environment Waikato indicated it planned to implement journey planning services in the near future and these are now operational. Other journey planners have since been developed by the Bay of Plenty Regional Council and commercial operators such as Naked Bus utilising Google Maps.

It should be noted the level of access to information regarding transport options is an important consideration. A high level of transport accessibility is not beneficial to communities if there is little or no information on how to access these transport services. Therefore, the usability and provision of information, as well as the data included on the journey planning websites were reviewed as part of this study.

The three organisations that provide journey planning services were contacted and interviewed. A comparison of the features provided by these organisations in 2008 is shown in table 10.1.

[5] Auckland Transport is now the council organisation responsible for the region's transport matters.

Table 10.1 Comparison of existing journey planning services in New Zealand (2008)

Service inclusion	Auckland Transport	GWRC	ECAN
Service logo			
Website	maxx.co.nz	metlink.org.nz	metroinfo.org.nz
Call centre	09 366 6400	0800 801 700	03 366 8855
Bus	Yes	Yes	Yes
Walk	Yes	Yes	Yes
Cycle	No	No	Partial
Train	Yes	Yes	N/A
Ferry	Yes	Yes	Yes (1 service)
Tram	No	Cable car	No
Engine software	IPTIS	IPTIS	IPTIS
User interface software	Consultants' product	Trapeze/AIM	OPCOM JourneyEngine
Journey preference option (cost/distance/time)	Yes	No	Only at initial query
Accessibility impairment options	No	No	No
Real-time data	Text message service for trains only	None	Yes, real-time bus GPS data
Health information calories burnt etc	No	No	No
Environmental information (petrol savings etc)	No	No	No
Vehicle features (super low floor etc)	No	No	No
Maps	Yes	Yes	Yes
Facility locations, (seats, toilets, drinking fountains)	No	No	No
Fare cost (public transport)	Yes	Yes	Yes

Note: GWRC has a separate walking and cycling journey planner that is not included in this review (www.journeyplanner.org.nz).

The following sections of this chapter discuss these journey planners in more detail. It is important to emphasise, the services provided by these journey planners may have been updated since the survey was undertaken.

10.3.1 MAXX – Auckland Transport

The data used for the MAXX journey planning software comes from a GIS server hosted by the Auckland Regional Council (now Auckland Council). Standard transport data on a range of transport modes is included. There is no separate GIS layer for walking and therefore it is assumed to be using the road network.

The MAXX journey planning website provides a high-quality user experience. The extended help option enables users to select valid location names from a list for their desired OD points. Advanced options also allow users to specify what routes/locations they do, or do not, want to use or travel through.

Many community points of interest are included such as banks, common retail chains (eg Dick Smith, Subway and Liquorland), education and healthcare facilities, as well as all streets. This feature is useful as it provides flexibility to users when entering their OD locations. This is because it is simpler for a user to remember 'BNZ Ponsonby' or 'Northcote College' than it is to know the physical street addresses of landmarks.

The MAXX website also includes school access and timetables, and although this information is not included in the journey planning service, it is beneficial for it to be provided on the same website. Users have confidence they can visit the MAXX website for all public transport information in the Auckland region. The MAXX website provides ample information and methods in presenting a planned journey; it also provides options based on time, cost or convenience so users can choose which route best fits their needs.

Public discussion forums are a useful feature of the MAXX website. These forums facilitate peer-to-peer discussion for MAXX users regarding how to use the website and public transport in Auckland. The forums allow users to post or answer questions and also allow for unofficial communication about any issues or suggested improvement.

The MAXX website has a high level of user accessibility, with options such as the extended help option mentioned previously. It also provides three font size options and a text only version of the whole site for use with computer interaction tools for those with impairments.

Despite the MAXX service providing many advanced features, there are a number of omitted services. Transport operators have buses that will accommodate wheelchairs, but users are unable to specify the use of only these vehicles when planning a journey. This presents a particular problem for those with mobility impairments as the journey planner cannot be used to find a journey with appropriate facilities.

10.3.2 Metlink – Greater Wellington Regional Council

Wellington's MetLink journey planning service provides all the core functions of journey planning and also allows selection of various transport modes. The website provides a list of suggested journey options after a request is made and requires users to then select a journey to view more details.

A modified version of the road centreline network is used as a walking network. This data has extra links added to allow for pedestrian access through public spaces. A walking network provides the advantage of reducing walking times where off-street routes are quicker and represents a real-world solution.

OD locations are not coded to the level of shop and services names as is Auckland's system, although major landmark locations such as Frank Kitts Park and Te Papa are included. Therefore, when entering location information, users may have to remember street names.

Currently only the MetLink call centre has the ability for users to request journeys that include only vehicles with specific facilities (eg wheelchair accessible buses). This system is planned to be incorporated into the website. Website user accessibility for sight-impaired users is poor.

Note that the GWRC has launched a separate walking and cycling journey planner which is not included in this review (www.journeyplanner.org.nz).

10.3.3 MetroInfo – Environment Canterbury

ECAN's MetroInfo website provides all the core functions of a journey planning service. It includes real-time bus information and estimates of real service arrival times as well as timetable information. Providing GPS based real-time data improves confidence in the public transport system, as users can be informed about the status of bus arrival times.

A useful feature of a real-time global positioning system (GPS) system is the status of buses expected at a bus stop can be received by mobile phone. While the system does not use the text message service, information requested from mobile phone users is available via wireless application protocol. This is comparable to having a mini web-browser on a mobile phone.

The MetroInfo system does not include a walking network so journeys are not fully optimised as walking is assumed to take place on the road network.

The MetroInfo journey planner also excludes some routes entirely. Services such as the 'City Shuttle' and the 'After Midnight Express' are currently excluded from the journey planner. While there may be valid reasons for not including these services in the journey planner, leaving them out reduces the software's ability to optimise journeys for some public transport users and is likely to reduce its usefulness.

MetroInfo has a number of significant landmarks loaded into the journey planning database, although this is not to the same level of detail as the Auckland system. Landmarks coded include education facilities, health facilities and public services.

Many Metro buses have suitable facilities for wheelchair users and those with mobility issues but there is currently no facility to plan a complete journey using only vehicles with these facilities.

Other gaps in usability of the MetroInfo website include a lack of school bus information and inability of the user to set up and save frequently travelled journeys.

In the future, journey planning on MetroInfo is expected to be expanded to include cycling and the possibility to plan multi-modal journeys.

10.3.4 Discussion

Journey planning services already available in New Zealand are a good starting point for planning the technical aspects of accessibility assessment. Data preparation, location geocoding and public transport scheduling experience from existing journey planners could be used to plan the implementation of an adopted nationwide data standard for transport service providers.

10.4 Geographic information systems

All transport models are GIS systems representing information about transport networks spatially but several bespoke GIS software packages are available that include features to make the process of building the models easier. These are often a good platform on which to build accessibility models. Network analysis tools can be used to investigate networks within a GIS. Common applications of network analysis tools include service area and closest facility investigations as well as routing optimisation including finding the shortest path and the 'travelling salesman problem' (TSP). The TSP referrers to a situation where the optimal route is determined to visit several sites in the most efficient manner.

Network analysis including TSP routing, is an important component of accessibility analysis as this technique is able to determine where people will probably go, how they get there and the associated cost (by time, distance or other defined measures) of getting there. Network analysis can also integrate with other GIS applications to combine data which impacts upon accessibility such as point-of-interest data, property data and land use activity.

Combining land use data with network analysis tools can involve a highly repetitive process that lends itself to automation. Where an analysis is undertaken to the level of individual properties, the quantity of data renders manual processing impractical. Several GIS products allow for the creation of model building and/or customised scripts to automate common analysis tasks. Examples include Python scripting for ArcGIS, ArcObjects software development kit (SDK) for ESRI products or MapBasic for MapInfo.

The ArcGIS Network Analyst product from ESRI enables users to build node edge networks from existing polyline vector data. Network datasets can quickly become highly complex as they are capable of storing features such as one-way streets, turn restrictions, speed limits and travel times. Building network datasets in ArcGIS is a complicated task due to the quantity and level of detail involved in a road network. A nationwide New Zealand road network dataset already exists; details of this dataset are provided later in this chapter.

ArcGIS has several methods for customising tools and automating analysis. The most simple of these is ModelBuilder. ModelBuilder for ArcGIS is a graphical tool used for constructing geoprocessing models. It uses a drag and drop approach. The output of each step is then run through various operations until the desired output is reached. ModelBuilder allows non-programmers to create customised models that can be run iteratively on large datasets. ModelBuilder is also able to export built models as python scripts for further customisation. These scripts can be adapted for use to utilise non-GIS specific programming techniques and modules; however, they are reliant on the ESRI geoprocessing engine for the GIS specific operations within the scripts.

Python scripting for ArcGIS is a mid-level customisation for ArcGIS. Python scripting allows users to quickly build simple tasks and execute them instantly using ESRI common objects and tools. Python is a lower level programming language than other complex applications that use ESRI common objects. It is easier to learn, read and produce models using Python than it is using other higher level programming languages such as C++ or Visual Basic.

ESRI products also allow the building of custom graphical GIS applications using the ESRI developer network (EDN). EDN is a subscription-based online community that gives developers the tools needed to create spatial software using ArcObjects and a SDK. ArcObjects is the core library of software components that makes up the foundation of ArcGIS. ArcGIS Desktop, ArcGIS Engine, and ArcGIS Server products are all built using the ArcObjects library. Programming and software development knowledge is essential for producing customised spatial applications under the EDN framework. These services require high-level programming skills that are beyond the skills possessed by most GIS analysts. It is not uncommon for these skills to be outsourced to consultants that specialise in the development of such products.

MapInfo produces a product called Routing J Server which is mainly used as an engine for web deployment of routing and driving direction applications. The product is not a desktop GIS solution and it is an engine upon which graphical applications must be built. Routing J Server can solve driving direction and route optimisation problems in a similar manner to ArcGIS Network Analyst.

Network analysis tools are provided for MapInfo by a company called RouteWare. RouteWare creates a routing engine called RWNET. RWNET allows developers to solve route-related queries through the creation of either desktop, web or server routing applications. It is used for custom queries by 'power users' who infrequently require a high-power routing engine. RWNET does not create a network dataset as such, but uses existing polyline spatial data with the correct attributes and the related files to perform network analysis. RWNET is flexible with input formats as it uses ESRI shapefiles, MapInfo MIF Files or MapInfo native TAB files as a network input. RWNET also exports to each of these file formats. RouteWare also provides a free topology checker for use with MapInfo. The topology checker is a stand-alone program that will check network dataset topologies and also identify the common network data issue of connectivity. Connectivity issues occur where links are not connected to nodes even though they are so close together as to appear connected. The topology checker will not correct topology problems; it is only able to identify them.

RWNET Server is a product designed to run on a GIS server. It is a flexible routing server that can be used with internet map services such as ArcIMS, MapXtreme or other MapServer products. More information about these systems is included later in this chapter.

RouteWare has also produced a graphical user interface for RWNET to give non-programmers the ability to use RouteWare graphically. This add-in for MapInfo, named RouteFinder, gives users access to common network analysis tools. RouteFinder is also available for ArcGIS as the RWNET SDK.

GRASS GIS is an open-source GIS application for UNIX, Mac and Windows users and has been developed over 20 years. GRASS for Windows is considered experimental. GRASS provides functionality for vector network analysis, but is not specific to transport. GRASS network analysis capabilities include solving common routing problems such as shortest path and the TSP, and can also solve optimum point locations for use in service area analysis. GRASS GIS is primarily a command line GIS program, so users who are used to graphical user interface (GUI) products such as ArcGIS and MapInfo may struggle to use GRASS. GRASS is highly functional and highly customisable but because GRASS is open source, most customisations are made to the source code which can be a difficult task, even for highly experienced programmers. Therefore GRASS is less likely to be an effective tool as although it is open source, it is relatively complex to create customised add-ins in comparison to other available applications.

10.5 Bespoke accessibility assessment tools

A number of GIS tools that focus on, or are built solely for public transport, have been developed for the purpose of assessing accessibility. These GIS-based modelling tools, most of which have been developed in the UK, may suit the needs of an assessment tool in New Zealand. They provide insight into the key functionalities that will probably need to be built into an accessibility tool for use in New Zealand.

Several accessibility tools that estimate travel time and cost in order to produce an accessibility indicator are described in Part 1 of this report. Accessibility modelling tools are separated into two categories. The first model type is a demand model with accessibility indicator functions typically based on traditional transportation model or the ‘would’ approach. These demand models are highly complex and similar to network transport models. They attempt to create simulations of demand based on the land use of an area. Accessibility is assessed from this demand model, so the analysis is of public transport frequency estimates as opposed to actual public transport timetables. The financial and time cost for demand-based accessibility modelling is high.

The second model types are those that have been developed without demand modelling capabilities and are based on the ‘could’ approach. These tools are less expensive to develop, more diverse and are often highly customised to a specific area. The majority of these custom tools assess whether or not groups are able to reach destinations, and then attempt to measure factors such as time and cost that are involved in reaching the destinations.

Several accessibility tools have already been developed, most of which have been produced in the UK by consultants, academic institutions or local government. A list of these tools is provided in table 4.2. All models include three core components:

1 GIS

2 a relational database

3 customised development or manipulation of GIS tools.

The tools analyse spatial data and public transport timetabling data in order to produce an estimation of time and travel costs for a particular set of OD locations.

The tools produced all involve each of the three components to varying degrees of complexity. Some models run on the back of desktop GIS software, and others are complete self-installing packages that include GIS functionality. It is crucial to note these tools have been developed around policy, and are customised tools for producing results according to accessibility planning specifications. Consequently, it would be difficult to simply adopt these tools in their current format and use them for accessibility planning in New Zealand. Rather, these existing tools and their functionalities should be seen as a guide to the development of a tool based on New Zealand accessibility indicators (once they have been developed) and the level of available data. It is also important to note the majority of the existing tools are used to measure access to public transport or to measure accessibility using public transport. Accessibility assessment in the context of this report will measure accessibility by all modes of transport, including walking, cycling, public transport and private motor vehicle. This is different from the majority of existing international customised accessibility assessment tools.

Common GIS formats, such as ESRI Shapefiles or MapInfo Native Tab files, are used in accessibility tools, either through direct importation, or indirectly through conversion software.

Public transport timetabling and scheduling information also needs to be set in the correct format before it becomes importable into accessibility models. An XML-based data format named TransXchange (DfT 2011b) is being increasingly used by the UK DfT for both journey planning software and in accessibility planning tools. There is no comparable data transfer protocols to the TransXchange data format in New Zealand; however, IPTIS, the journey planning software developed by Jeppesen (a Boeing company) – the engine most used by New Zealand journey planning websites in 2008 – requires a standardised public transport scheduling system. Even so, there is a trend towards the use of a Google public transport standard (Google Transit Feed) and the Auckland and Wellington websites allow users to download the public transport data in this format.

The widespread adoption of a customised international accessibility assessment tool would require the adoption of the data standards used by the tool. All New Zealand data would then be required to run through a conversion process and be continuously maintained or alternatively standardised in an agreed format.

To develop a useful toolkit some tasks can be processed generically nationally (or internationally as Google Maps has shown) using server-based analytical tools. There are other tasks that need specific local knowledge and data and these should build on the general information available in the national tool.

The software supplier industry that seeks to sell large volumes of generic products has been involved in developing bespoke accessibility assessment tools around the world. However, generic products are more suited to generic problems like transport supply and demand, rather than the niche issues and locally specific challenges that accessibility planning seeks to tackle.

To help develop accessibility analysis capabilities, DfT partnered with a number of software developers in the UK to create tools for specific applications. These included the development of the Capital model for London, the development of the Accalc analysis for Scotland and subsequently for calculating the national accessibility indicators, and the investment in Accession for use by local authorities without their own modelling tools.

Accession is described in detail in section 10.5.1 and in appendix A but it is also worth noting that both Capital and Accalc are run on servers rather than PCs. The intention of the server-based approaches is that they can complement other sophisticated server based approaches like Google Maps and Bing Maps. Most data sharing systems are organised via servers with network maps such as Open Street Map increasingly providing global opportunities to create online data about networks and routes.

It was noted in the UK when developing accessibility planning that most planners needed an 'expert system' rather than a model. The modelling capabilities already existed in GIS, databases and transport models but support was needed for planners on the questions they should be asking, where they might find the answers, and in automating data collection and management. Accession goes some way towards assisting with the data management tasks but many local authorities have not used it, as intended by DfT, to ask questions about who might face gaps in transport systems (DfT 2004).

10.5.1 Citilabs Accession Software

Prior to the launch of accessibility planning guidance in the UK in 2004 ACCMAP was the most widely used software by local authorities. DfT therefore partnered with the developers of ACCMAP to add indicator calculation functions that were likely to be needed for more integrated accessibility analysis. The upgraded software was named Accession and marketed by Citilabs UK. Accession is limited to local models as in common with ACCMAP. The software is based on a Microsoft Access platform that restricts the file sizes possible. Accession has been marketed by Citilabs outside the UK including to local authorities in New Zealand.

The tool helps users to manage spatial and timetable-based data inputs but is designed for compatibility with UK data sets and in other countries there are different data standards, particularly for the public transport data.

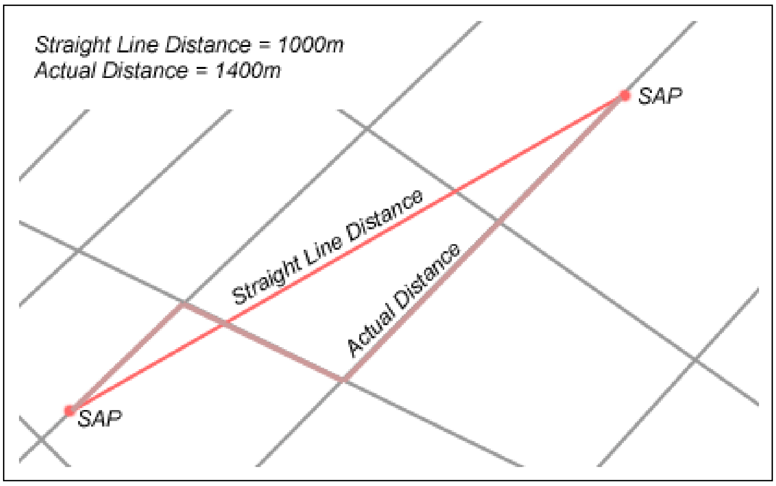
Accession and other similar tools allow users to create and delete data for executing 'what if' queries and understanding the impacts of planning decisions, and include both spatial and tabular data. Features such as this, as well as the ability to import and export various GIS and transport data formats, are generic functionalities and Accession seeks to strike a balance between policy relevance for accessibility planning and the same flexibility available in generic GIS software such as ARCinfo.

Although its primary purpose is for use with public transport data, Accession also includes analysis of walking, cycling and vehicular transport although there are some simplifications with regard to the walking and cycling analyses in particular, which reduce the quality of the outputs.

In assessing the suitability of Accession for analysis in New Zealand it is of note that Accession does not use specific walking or cycling networks for accessibility calculations, rather walking and cycling trips are based on road centreline data, and walk and cycle speeds are set as a model parameter. This reduces the accuracy for neighbourhood accessibility analysis.

Accession also gives the option to use a straight line 'as the crow flies' walk distance for the calculation of public transport interchange (stop to stop) and connection (origin to network or origin to stop) trips. This straight line distance is converted to a generic detour distance (actual distance travelled) using a conversion factor of 1.4 (as shown in figure 10.1). This is a significant assumption considering the variability of walking environments and although it can be varied by the user, it would require validation to each study area or each part of the study area.

Figure 10.1 Straight line walk distance factor diagram



The limits on file sizes also mean that Accession is not suitable for more strategic analysis covering wider areas. One way of increasing the size of the model is to use a larger zone size and to alter the walking and waiting times to reduce the computation demands when estimating the journey times.

In the New Zealand analysis the model was assessed over various time periods limiting the maximum travel time. The time interval set is a trade off between accuracy and calculation time. For example, reducing the sample time to five minutes doubles the processing time but cuts the error in journey time calculation by 75%.

To reduce processing times, walking, cycling, public transport or vehicle networks can be further simplified by reducing the number of modelled nodes. This approach requires a testing methodology to find the optimum network quality which will reduce processing time, but will not compromise the quality of accessibility calculations.

A more detailed description of Accession including a trial applied to Christchurch New Zealand is included in appendix A.

10.6 Data

The availability of land use and transportation data plays a critical role in the assessment of accessibility. The difference between existing data and what is required for the assessment of neighbourhood accessibility is significant.

Data pertinent to accessibility assessment will need to be sourced from a combination of central government, local government and commercial spatial data providers.

The lack of a standardised data exchange format will slow the deployment of an accessibility assessment tool although the opportunity to create best practice formats as part of this process should be encouraged.

Datasets required to operate an accessibility assessment tool include the following:

- Parcel boundaries: if feasible, accessibility assessment for detailed areas such as single properties should be undertaken. Alternatively address points can be used.
- Neighbourhood boundaries: meshblock data boundaries are sufficiently small enough to define a neighbourhood or zone for an accessibility model. If these are too narrow ranging then area units can be used to define neighbourhoods.

- Land use or planning zones: this data will provide an indication of where activities take place and also allows neighbourhood boundaries to be defined by land uses.
- Land-activity use: either defined by individual properties or by point data, land-activity data is essential in defining the origin and opportunity destination locations.
- Road network data: this should include both road centreline data and features associated with the network such as turning restrictions, speed limits and traffic flow direction information.
- Walking and cycling routes: these should include travel times. Compared with road data, walking and cycling routes often allow access to spaces that motor vehicles cannot reach. This data is essential for making accessibility comparisons between different modes of transport.
- Public transport data (including public and private operators): this should include routes, stop locations, time table information and fares.
- Existing travel data: the identification of key trips currently undertaken will help aid the formulation of core accessibility indicators.
- Demographic data by meshblock: this is essential for identifying where the population lives and identifying population groups by location.

The latter two bullet points are essential information required for developing accessibility indicators.

Other datasets that would be beneficial for inclusion in accessibility assessments include:

- provisions for those with physical disabilities on public transport facilities
- hours of operation of land use activities
- quality of the walking/cycling environment
- other key deterrence factors to access including safety, security, information provision and physical features or barriers.

The following subsections discuss data availability from various sources including government-owned data, commercial data products and data available at no charge.

10.6.1 Government-owned data

Due to the nature and perceived benefits of measuring accessibility, it is expected the NZTA, as a central government organisation, will have a higher-level privilege and therefore be able to obtain essential data more easily. Several datasets already exist within central, regional and local government that will play an essential role in assessing accessibility.

Land Information New Zealand (LINZ) maintains the core record system (CRS) for New Zealand property and land parcel information. The Ministry of Transport holds ongoing NZHTS data. The NZHTS data was supplied for use with this project.

Statistics New Zealand collects census data every five years but due to the Christchurch earthquake, the 2011 Census was cancelled and the next one will now be in 2013. Spatial boundaries including meshblock and area units are distributed within local and regional government boundaries. Statistics New Zealand distributes the demographic information related to these meshblocks through the delivery of census data.

The majority of localised data is collected through regional and local councils.

10.6.2 Commercial data products

Critchlow Limited (Critchlow) is the provider of a data product named NationalMap. NationalMap is a nationwide New Zealand vector dataset of locations for a broad range of both natural and cultural features. The core data product contains add-on products including routing and road assessment and maintenance management (RAMM) data. Critchlow is New Zealand's sole distributor for MapInfo products and the routing data included in the NationalMap product is optimised for routing within MapInfo. At the time this research reviewed the NationalMap data, NationalMap2 was the most current version. Critchlow have since released NationalMap3. NationalMap2 included the following data:

- Road centreline polyline layer: this includes attributes for the street name, identification, legal status, surface type, hierarchy, speed limit, average speed and one-way direction references.
- Bridges point layer: this includes attributes for the bridge names, bridge identification, road identification, road name and features under and over the bridge.
- Traffic lights point layer: this includes attributes for type, as well as traffic and pedestrian-related information.
- Turn restrictions point layer: this includes attributes for road identification, secondary road identification, road name, secondary road name and restriction type.

Roading networks for routing applications from RWNET (described in section 10.4), are built based on routing data mentioned earlier. The application uses the road network and incorporates features such as traffic lights and turn restrictions into the data for routing. Features need to be entered in the correct location in order for points associated with the corresponding road network intersections to be accessed.

RAMM data provided by Critchlow is submitted by local councils and furnished by Critchlow for on-sale to others. CJN Technologies Limited specialises in the development of software for the New Zealand roading industry including the development of RAMM. RAMM data supplied by Critchlow includes attributes such as road name, road identification, traffic counts, length and width of road, pavement type, urban/rural classification and the number of lanes.

Other data relevant to accessibility is provided mostly as point data in NationalMap2. A summary of data relevant to accessibility assessments in included in table 10.2.

The other provider of nationwide spatial data in New Zealand is Terralink. Terralink does not distribute GIS software products although due to market demand, its outputs are primarily in ESRI format. The Terralink dataset provided to the researchers as part of this project was substantially more detailed and contained more datasets than the NationalMap2 product.

Terralink distributes LINZ CRS data. This dataset is the official dataset for maintaining core land records in New Zealand. The CRS system also includes point data for address matching, which is a significant dataset to supply given the production of such a dataset can be technically challenging. CRS data relevant to accessibility assessment includes address data, rail and road centrelines and land parcels.

Terralink also maintains a point of interest database. A summary of the points of interest that are relevant to neighbourhood accessibility is included in table 10.2. The point of interest database also contains relevant information about the particular feature. For example, each automated teller machine (ATM) that is geocoded contains information about the bank the ATM operates for, and parking data includes opening hours and standard parking rates.

Terralink supplied data also includes selected land use files. These layers are not as detailed as those supplied by local councils given the level of detail included in district plans.

Terralink also supplies a roading network that has been prepared for use with ESRI's Network Analyst extension. This is supplied ready for analysis and includes routing information such as turn restrictions, intersections, one-way attributes, road hierarchy, speed limits, surface type, legal status, number of lanes, travel time based on speed limit and turning attributes.

Table 10.2 Commercial data sources

Data	Critchlow Limited	Terralink
Road centreline	Yes, RAMM	CRS road
Road surface	RAMM	Road network
Seal width	RAMM	No
One way	RAMM	Road network
Turn restrictions	Point data	Road network
Speed limit	RAMM	Road network
Journey speed	Derived from speed limit, RAMM	Derived from speed limit, road network
Traffic volume	RAMM	No
Traffic lights	Point data	No
Traffic lanes	RAMM	Road network
Compiled network	No	Yes
Road length	RAMM	Yes
Road travel time	No	Road network
Rail data	Yes	Yes
Address data	No	Yes
Land use	Partial	Partial
Land activity	No	No
Health services	Yes, although no local medical centres	Medical centre and hospitals
Education facilities	Schools and other	Schools and tertiary institutions
Post offices	No	Yes
Banks	No	No
ATMs	No	Yes
Churches	No	Yes, not detailed
Information centres	No	Yes
Parking lots	No	Yes, with costs
Petrol stations	No	Yes
Retail locations	Broad polygons	Shopping centres
Public recreation space	Yes, not detailed	Golf courses, camp grounds
Bus terminals	No	Yes
Post code regions	Yes	No
Suburb outlines	'Community of interest', low resolution	Yes

Note: 'land use' relates to the general use of the land, eg business or retail, whereas 'land activity' is more specific, eg post offices.

10.6.3 Data availability in New Zealand

The current supply of relevant data falls significantly short of the ideal levels required for accessibility assessment. However commercial mapping approaches such as Google and Bing Maps include a wide range of commercially available data on roads and land uses. As public transport data has become more widely available in other countries Google Transit[6] has also allowed mapping of access to services from any point location. However data for public and private public transport services, in a standard format and at affordable cost, is not available in New Zealand's major cities and the lack of data for towns and rural locations may result in reduced quality of accessibility assessments until this shortfall is rectified.

The desired data and the most likely data source, as well as other possible sources of data are listed in table 10.3. It should be noted that some of this data is not available or varies in quality depending on the source; local councils, in particular, have data at different levels of detail and quality.

Table 10.3 Data requirements and sources

Data	Primary source	Other sources
Parcel boundaries	LINZ CRS via Terralink	
Neighbourhood boundaries	Statistics NZ meshblock or area units	Terralink community boundaries
Land use or planning zones	Local councils	
Land activity locations	Local councils/Ministry of Transport/ existing research	Critchlow, Terralink, LINZ, Zenbu
Road network	Critchlow/Terralink	Local and regional councils. RAMM
Compiled road network	Terralink	
Cycling network	Local councils	Regional councils
Walking network	Local councils	Regional council
Public transport data	Regional councils	Local councils
Existing household travel data	Ministry of Transport	
Demographic data	Statistics New Zealand	
Hours of activity operation	Local councils	Local business organisations
Quality of active mode networks	Local councils	Key stakeholders, eg Living Streets Aotearoa
Other key deterrence factors	Ministry of Transport	

The lack of immediately available data suggests data will need to be collected in order for the successful development and implementation of accessibility planning tools in New Zealand. The collection of new datasets is often a significant project in its own right and therefore collecting all missing data is not immediately feasible. It is important during the early stages of accessibility planning that priorities are set for data collection and communication of intentions are broadcast to other entities that may benefit from the planned collection of any such data. Forming partnerships for data collection can often be beneficial both economically and strategically for all parties.

The format of public transport and journey data is also an issue for accessibility assessment. The UK has several data exchange standards such as TransXchange and RTIG-XML. No such standards exist in New Zealand for the exchange of data. A customised accessibility assessment tool will require a

[6] http://maps.google.com/help/maps/transit/partners/

standardised input for public transport and journey data exchange and this project could be the catalyst for the development of a New Zealand standard.

10.6.4 Other data sources

A recent development in geospatial data management in New Zealand is the creation of a website for facilitating the exchange of spatial data in New Zealand. The website www.koordinates.com contains information about what data is available and who or where it is available from. The site includes the ability to browse or search for data, pay for data online and also download free data where it is available. An example of the worthiness of this website is that the Department of Conservation's 'recreational opportunity spectrum' is available. This particular dataset will assist in locating recreational activities as points of interest.

In addition, an open source point of interest database exists within New Zealand. The website www.zenbu.co.nz facilitates a user community to locate features using a Google Maps interface. Users can search and find community features as well as contribute to the database by adding their own point of interest data. When the researchers interrogated the Zenbu dataset in 2008, over 70,000 points of interest had been geocoded and were downloadable as a single table which contains x, y coordinates, description and tags (keywords). In 2012 the Zenbu database had about 105,000 points of interest and was growing. While the quality of the Zenbu database is not verified because it is only audited by its own user community, the volume of data within this database has the potential to provide a large benefit for accessibility projects while official datasets such as this are developed. It should be noted that in 2008 other point-of-interest datasets similar to this contained less than 10,000 points nationwide.

There are several locations on the internet where spatial data is available for downloading at no cost. Websites from commercial operators within the GIS industry such as www.geographx.co.nz and www.ollivier.co.nz in New Zealand often offer free data at a lower resolution or degree of detail than the commercial products they sell. Although these non-commercial products are probably still of good quality, it is not recommended that free sources of data found on the internet are used for accessibility assessment due to issues of data quality and completeness. Alternatively the data should be verified as correct via local knowledge and checking data quality.

Statistics New Zealand has made available a set of spatial data that will provide an essential role in assessing accessibility. Digital census boundaries, which at the most detailed level include meshblocks, became available free of charge from July 2007. Census data is an essential dataset for neighbourhood accessibility planning as each meshblock can be joined to census data for spatial analysis. This provides an important source of geodemographic data.

10.7 Territorial authority survey

10.7.1 Introduction

The aim of this research was to develop an accessibility assessment tool ultimately for use by local authorities in New Zealand. Therefore, a survey of local authorities in New Zealand was carried out to establish the resources they have available (including human, software, hardware and data resources). This would assist in understanding the bounds in which an accessibility tool should be developed to ensure local authorities would have the ability to use or support it.

Abley mailed a resource survey to all 84 regional and local councils in New Zealand in 2008. The survey questions covered human resources, hardware and software capabilities, and the data resources held by each council, with a focus on GIS and transport resources. The survey was completed by 60 of the 84 councils (71%) response rate) and analysis of the survey responses is presented in the following sections. A copy of the resource survey questionnaire is included in appendix B.

10.7.2 Human resources

The most common type of management structure in local councils is to have a specific GIS team working as a corporate service. Some large council departments such as transportation and asset management departments have their own dedicated GIS staff. Smaller councils are more likely to outsource complex GIS and customisation work. GIS staff numbers are generally related to the overall size of the council. Forty-two percent of the council responses indicated they have the ability to internally produce custom GIS applications.

It is common for councils to have a specific transport department. The size of transport departments is also a reflection of the overall size of each council. Transport staff numbers appear slightly higher than GIS staff. This result is not surprising given many small councils rely on external GIS consultants. Furthermore transport planning and management is a traditional council role and transport staff will often employ GIS concepts without the need for dedicated GIS staff members.

The survey responses highlighted a shortage in transportation staff and difficulty in filling vacant transport positions.

10.7.3 Software resources

The type of desktop GIS software used by councils provides a rough indication of the capability of council GIS departments. It is also common for councils to use products common to a corporate vendor for ease of data interchange and interface familiarity or economic reasons such as ‘package discounts’. Seventy-seven percent of respondents use only one type of desktop GIS product.

The two major desktop software products used by councils in New Zealand are ESRI ArcGIS and MapInfo Professional. Of the councils who responded to the survey, 44% use ArcGIS and 42% use MapInfo. Together 77% of all councils use either ArcGIS or MapInfo, and 10% use both ArcGIS and MapInfo. Of the respondents who do not use either ESRI or MapInfo products, 50% use Intergraph GeoMedia and the remaining 50% do not have inhouse GIS desktop products. Based on the population of each council constituency, the average population for local councils who use ArcGIS is 98,005 people compared with 36,149 people for MapInfo Professional. This suggests larger councils are more likely to use ArcGIS.

Uncommon situations or comments made in regard to desktop GIS products included the use of AutoCAD for GIS/mapping work and the use of an application server allowing desktop GIS using Genamap.

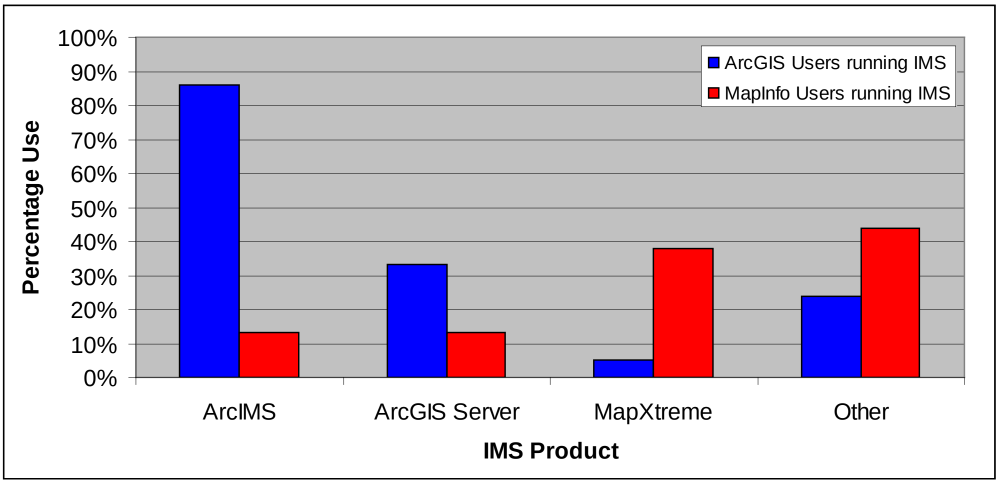
When making comparisons between ArcGIS and MapInfo, the survey shows that of those who use ArcGIS, 22% also have MapInfo, and of those who use MapInfo, 41% also use ArcGIS. The higher percentage of MapInfo users who also use ArcGIS products suggests neither of the two products completely fill the functionality or pricing needs of councils; however, ArcGIS fulfils more desktop GIS needs than MapInfo Professional.

No responses included any comments or indications regarding the use of open source or free desktop GIS software.

Common statements made by survey respondents regarding GIS resources included a planned upgrade from ArcIMS to ArcGIS Server, as well as the use of Citrix servers to run GIS desktop applications as thin clients[7] in order to save on licensing costs.

Internet map servers have a high rate of use within councils. Thirty-five percent of responses run external (internet) map servers and 77% run internal (intranet) map servers. Ninety-one percent of ArcGIS desktop users run IMS and 73% of MapInfo users run IMS. The percentage use of IMS common software products compared by desktop type is shown in figure 10.2.

Figure 10.2 IMS software use compared by desktop software used



Users who run ESRI desktop GIS products are also likely to use ESRI products for other GIS applications within their organisation. This is not an unexpected result and a council choosing ESRI, will use ESRI to provide software for many, if not all, of its common geospatial application needs. ESRI provides GIS software for desktop, server, mobile devices and also provides products for spatial data storage, programming libraries and software development kits (SDK).

This relationship is also similar between MapInfo Professional desktop and MapInfo's IMS product, mapXtreme, although the results do not show as strong a relationship. In general, it appears that councils look to ESRI as their 'one stop shop' for all GIS applications if they use ArcGIS as a desktop application, whereas those who use MapInfo are more likely to seek a product independently of the existing software used for desktop GIS. Councils that responded with 'other' when questioned as to which IMS software was chosen, also stated MapInfo or 'other' as their desktop GIS product.

Transport modelling software is used by 29% of local and regional councils. The majority of these use Tracks. Other transport modelling software commonly used includes EMME/2 and Saturn. Local councils also mentioned using Tmodel and Cube. TransCAD is not used by any council for transport modelling. It is noteworthy that only one implementation of transport modelling is linked to journey planning software (Auckland Transport).

In 2008 journey planning services were provided by three councils as outlined in the earlier part of this chapter. All three journey planning services ran on the IPTIS engine and had a high level of customisation.

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[7] A thin client (sometimes also called a lean or slim client) is a computer or a computer program which depends heavily on some other computer (its server) to fulfil its traditional computational roles. (http://en.wikipedia.org/wiki/Thin_client accessed November 2012)

Of the surveys that included responses to questions regarding operating systems, all respondents used either Windows XP or Windows 2000 as their common operating system. The adoption of Windows Vista by councils was minimal. No indication was given that Apple, UNIX/Linux based or other open source software is used as a common operating system by councils.

10.7.4 Hardware resources

GIS software and processes often involve complex and computationally intensive processing as well as significant levels of graphical processing. This requires high-end hardware capability. A summary of council responses to questions relating to 2008 hardware for regular desktop computers is shown in table 10.4. This indicates that councils who keep hardware up to date will not face difficulties running desktop GIS applications such as ArcGIS or MapInfo.

Table 10.4 Hardware capability of local and regional councils (2008)

	Standard	Better	Best
Processor speed	**<2GHz**	**2-3GHz**	**>3GHz**
All	17%	60%	23%
ESRI users	14%	61%	25%
MapInfo users	14%	57%	29%
RAM	**<1GB**	**1-2GB**	**>2GB**
All	27%	53%	20%
ESRI users	29%	50%	21%
MapInfo users	29%	43%	29%

With the majority of hardware profiles sitting in the 'Better' category, councils appear to be sufficiently resourced to run GIS software. Specialised workstations within some councils had higher specifications, but these were not considered to be desktop computers. There is no clear distinction between the hardware capabilities of those that run ArcGIS for desktop GIS and those that run MapInfo. Running GIS analysis through a client/server model will put more of the demand on the server and less on a client computer when compared with desktop GIS applications.

10.7.5 Land use data resources

An essential part of any GIS analysis project is to have accurate and up-to-date spatial data available. Data pertinent to this project can be categorised as either transport data or land use data.

Nationwide land use and transport data sets are either captured and periodically updated under contract to LINZ or are considered to be data products held (and sold) by private companies. Data available at a national level includes road centreline and cadastral data. Section 10.6 of this report discusses national datasets available from private companies and government organisations.

Several essential datasets needed for accessibility assessment are not held nationally, and are instead collected by regional and local councils. Locally collected data is not of consistent quality when compared across New Zealand because local councils have an assortment of priorities in both the collection and maintenance of data.

Ninety-four percent of councils have land use or land-zoning data sets. In reality, this number is likely to be slightly higher as many of the responses did not answer this particular question. Almost all councils indicated they hold land parcel data which is already available nationwide. Further to that, it is a requirement that all territorial authorities hold a district plan, of which a significant component includes land use planning.

Land use is an important base dataset for accessibility planning although additional datasets such as vacant land parcels and land activity will further improve accessibility assessments. These datasets provide a higher level of detail on activities and parcels of land that currently exist. Sixty percent of councils indicated that spatial data for vacant land is held and 56% indicated they hold land-activity data. Many comments were added to the survey responses concerning land information. Land parcels information was commonly mentioned as being LINZ CRS data and land use or zoning data was captured from the district plan. Vacant land data was often taken from councils' rating information.

10.7.6 Transport data resources

According to the survey, 83% of councils indicated they held RAMM data. Data relating to traffic volumes and the maintenance standard of various roads is contained in RAMM. Road centreline data is an essential dataset for accessibility assessment and is the base of other datasets such as public transport, walking and cycling routes. Road centreline data is available at a national scale from a number of sources.

Road hierarchy information is a common part of council datasets with 81% of councils indicating they hold road hierarchy data. In many cases, this information is simply an attribute of the road centreline data, so entering road hierarchy data is a simple and inexpensive task once the hierarchy policy has been determined.

Where public transport services are provided by local councils, data relating to bus routes has a high capture rate. There is limited capture of associated public transport data such as fare sections, timetable information and bus stop facilities or public transport provided by private operators. Public transport data is traditionally held by regional councils as opposed to local councils, although often common sense defines which organisation holds and maintains this data.

Public bus data is generally updated as needed and data quality is guided by the quality of the road centreline data. GPS is often used along routes as a validation method. Real-time provision of bus information in 2008 was only provided in Christchurch; although at that time there were plans to implement this in Auckland and Wellington. Those other cities are in various stages of implementing real-time information.

Ferry service data is held by most councils that provide commuter ferry transport. This includes ferry routes, port locations and timetable information, and the data is updated as required.

Public commuter train data is not common as very few locations have commuter train services. Where they are in operation, commuter train data is held. The data held is high quality and is accompanied by train station point data and timetable information.

Cycle network data is held by councils that serve larger towns and cities. Off-road cycle networks have been captured by the majority of councils who hold cycle network data although other related information such as whether there are cycle racks on buses, cycle friendly intersections and bicycle travel times are not well captured.

The question regarding pedestrian access was not understood by many respondents of the survey. Despite this, 23% of councils indicated they hold pedestrian access data, with 13% indicating they hold off-road pedestrian access data. Several comments were made that pedestrian access data was assumed to be footpath information, which is held in RAMM databases. Related information such as road crossings, rest points and travel time are not well captured. Overall, walking data is not a common dataset among councils, and of those who do hold pedestrian access data, the datasets are not complete.

Thirty percent of councils indicated they model their transportation networks. Of this group, the majority model their own town or city. Most respondents run one large model rather than several small transport models and there is no clear preference between three step and four step models. The validation year for the models was generally 2001 or 2006 to coincide with census demographic data. Of those who run future forecasting transport models, the years used are generally 2011, 2016 and 2021, again coinciding with expected census years.

Transport modelling is carried out on all roads by the majority of those who undertake modelling. There were very few responses which indicated that only major or strategic roads are modelled. The majority of responses indicated a meshblock or a similar sized zone model is used. Very few responses indicated the use of area units or larger zones in transport models. This illustrates a preference for undertaking transport modelling at a high level of detail.

10.8 Data preparation

10.8.1 Networks and land use

The data required for performing accessibility calculations includes transport networks, population information, origins and destinations. The assembly of comprehensive destination and transport data is a vast task. Therefore, to ensure a practical value for money approach it is important to identify the indicators required before assembling the data.

Data sources for New Zealand have already been identified and data preparation is underway although there are many incomplete or non-existent datasets. For pilot work undertaken in Christchurch, the following datasets were created:

- networks:
  - bus – including bus stops, routes and timetables
  - cycle – based on road centreline and includes one- or two-way directions and off-road cycle paths
  - walking – footpaths on both sides of the road, different crossing types and off-road walking links
  - private vehicle – based on road centreline and including one or two way directions.
- land uses – for core indicators (expanded from SEU 2003 core activities):
  - primary schools
  - secondary schools
  - tertiary education institutions
  - employment
  - hospitals
  - primary health care (GPs)
  - supermarkets
  - convenience stores
- land uses – extension
  - post receivers
  - post offices

- recreational sports fields
- chemists
- churches
- banks
- libraries
- playgrounds
- dairies
- petrol stations
- retail:
  - regional centres
  - district centres
- ATMs
- swimming pools (private)
- swimming pools (public)
- recreational centres (private)
- recreation centres (public)
- video stores.

To aid processing, all public transport services and unused locations outside the defined area for analysis were removed using a clipping tool available within the software. This methodology demonstrates an important concept for accessibility, ie limiting the analysis and tidying data as much as possible before calculations are undertaken. Many GIS functions such as clipping and indexing using spatial joins are performed prior to undertaking accessibility calculations to reduce calculation resources.

Public transport accessibility modelling can be undertaken by using detailed timetable data or simple frequency data. UK public transport timetable data is now generally transferred between organisations using the TransXchange standard (DfT 2011b).

> *TransXChange is the UK nationwide standard for exchanging bus schedules and related data. It is used both for the electronic registration of bus routes (EBSR) with Vehicle and Operator Services Agency (VOSA) and the Traffic Area Networks (TAN), and for the exchange of bus routes with other computer systems, such as journey planners and vehicle real-time tracking systems.*
>
> *The format is a UK national de facto standard sponsored by the UK Department of Transport. The standard is part of a family of coherent Transport related XML standards that follow GovTalk guidelines. It is also used by RTIG.*
>
> *Version 2.0 of the TransXChange standard was released in April 2005. Version 2.1 was released in February 2006. Version 2.4 was released in Feb 2011. TransXChange is an approved Govtalk schema.*
>
> (from www.dft.gov.uk/transxchange/)

There are many proprietary formats used by public transport journey planning software companies. If a nationally consistent data format is not already available, then a significant initial task is to create one. One of the main benefits would be the provision of integrated public transport information. Making the data available widely would allow Google Transit and other providers to ensure freely available integrated public transport information across New Zealand, not just for modelling purposes.

New Zealand does not have standards such as TransXchange for standardising public transport data. Consequently implementation of a New Zealand accessibility assessment tool could result in the creation of various ad hoc public transport data exchange standards and this is an important matter that will require resolution.

The use of a common public transport interchange format will be an important step forward in the use of data interchange standards and the development of a New Zealand accessibility tool. It is probable that the Google Transit Feed has filled this gap in New Zealand by default given it is a published format by Auckland and Wellington councils.

10.8.2 Geodemographic data

Geodemographic data describes geographical units with populations of broadly homogeneous socio-economic and cultural characteristics. This data is more useful than standard demographic data as it includes a spatial dimension. For example, at-risk groups in particular locations can be identified by geodemographic data. In New Zealand, census data is a good source of geodemographic information and is supplied by meshblock.

Another application of geodemographic data is job destination data can be weighted by the population relating to particular datasets. For example, attractiveness values are assigned to meshblocks or defined geographic areas with more jobs per unit area than for similar areas with fewer jobs per unit area.

11 Part 2 conclusions

Accessibility planning is currently undertaken on an ad-hoc basis as there is currently no standard way that accessibility is being measured in New Zealand. Nevertheless, there are examples of projects where accessibility analysis approaches are being used.

Existing accessibility modelling tools in other countries have been developed to the specifications of those countries. The data format and exchange required by these tools is different from that available in New Zealand. This makes these tools less transferable to a New Zealand situation.

Accession, a bespoke accessibility modelling tool developed in the UK, was trialled in a Christchurch case study. The trial highlighted some of the constraints and limitations to using Accession in New Zealand, in particular, the different data exchange formats required and the fact that Accession does not consider the reach to multiple opportunities or the weight of those multiple choices.

Existing journey planning services provided in New Zealand are the closest automated tool to accessibility analysis software in New Zealand. In 2008 three regional councils provided journey planning software with varying levels of sophistication.

Local and regional councils have GIS and transport modelling resources to run a customised accessibility assessment tool, but they do not necessarily have the resources to develop or maintain one.

There is no clear leading desktop GIS application used in New Zealand. Consequently developing a product to suit one GIS software platform over another is likely to disadvantage a significant number of users. Rather it is more important to develop a clear methodology that can be implemented in various GIS software packages.

The lack of a standardised public transport exchange data format presents an issue for inputting public transport timetables and frequencies. Conversion or digital entry of this information should be simple, standardised and easy to implement. The IPTIS journey planning software that was used by all existing journey planning service providers in New Zealand in 2008 is a good source of experience when considering these issues. Latterly though, Google Transit Feed has filled this information gap and has by default, and in the absence of an alternative, become the New Zealand standard.

Where spatial data such as land use information is lacking, the collection of data will be essential for carrying out robust assessments. A factor to consider when undertaking this data collection is the intention of accessibility assessments to be an ongoing process as opposed to a one-off project. Spatial data collected for accessibility assessments will also have value in other areas. A partnership approach to spatial data collection could prove highly beneficial particularly among departments within a local government organisations and private companies.

An accessibility tool developed using an existing GIS package must be able to undertake complex calculations resulting in good quality graphical outputs. For example, the routing function included in ArcGIS Network Analyst provides functionality for optimising routes and recording deterrence variables or costs along the route. GIS packages are efficient for land use analysis and allow for the dynamic generation of OD pairs for route finding.

In order to create the very large UK national model all analysis was undertaken within a SQL server database and a bespoke routing algorithm was programmed based on AutoPTpath. The data was then managed in Accalc providing the flexibility needed to create the 568 different UK accessibility indicators. This is a much less expensive solution than purchasing licences for software but still leaves the flexibility to analyse any individual table or data set within commercial software such as ARCinfo GIS.

The requirement for customisation and other technical issues is introduced when working with public transport timetable data as frequency analysis and journey planning are not functions commonly built into GIS packages. This requires a model build within the data format created or adopted in New Zealand.

The successful adoption of the accessibility tools at a neighbourhood and local level requires as few barriers to use as possible. Server-based GIS designs, including web server designs, could be an acceptable solution to providing a tool for all users at very little or no hardware cost.

PART 3: NEW ZEALAND ACCESSIBILITY: MODELLING METHODOLOGY

12 Introduction to Part 3

Part 3 of this report discusses the development and proof of concept implementation of the proposed accessibility methodology that includes walking, cycling, public transport and private motor vehicles. It also includes measured travel behaviour and is able to model increasing accessibility with increasing opportunities that are deemed to be in reach based on a continuous measure.

The approach proposed builds on existing modelling capabilities, for example adding the dimension of land use opportunities and people's capabilities to existing narrower mobility analysis solutions. However it also seeks to ensure there is a practical and affordable toolkit for assessing accessibility with analysis costs commensurate with the budgets likely to be available for this sort of work.

12.1 Structure of Part 3

Chapter 13 describes the development of 'travel time distribution' values for New Zealand using data from the Ministry of Transport's New Zealand Household Travel Survey (NZHTS). It includes a brief overview of the NZHTS, the methodology used to develop origin-destination (OD) trip matrices, a description of the travel time distribution parameters and how they were identified, and a summary of the deterrence parameters that were calculated. It also makes a brief comparison with results from the UK.

Chapter 14 outlines the steps involved in the creation of the four network datasets; namely the walking, cycling, public transport and private vehicle datasets.

Chapter 15 details each of the seven steps in the accessibility calculation methodology. It begins with a description of the process required to prepare the input datasets for the accessibility calculation. Two distinct phases of the methodology are then discussed. The first phase involves performing the shortest path network calculations for each activity across each of the four networks. The second phase involves combining the results of the network calculations using a weighting matrix to create comprehensive accessibility scores across a study area.

Chapter 16 applies the accessibility calculation methodology, in a case study of the city of Christchurch, New Zealand. Comprehensive accessibility scores were calculated across the city at a meshblock level to provide a baseline dataset. Two scenarios, the construction of a new hospital in Halswell and the construction of a bridge across the mouth of the Avon-Heathcote Estuary were then modelled and the results compared to the baseline dataset in order to quantify the accessibility gains from these two scenarios.

Chapter 17 presents a discussion of the methodology. It examines how to interpret the outputs of the accessibility calculations and proposes some applications which have been made possible due to the development of this accessibility methodology.

Chapter 18 concludes the report drawing together the ideas presented throughout the report.

Chapter 19 includes areas of further research and recommends the next stages of work to develop and refine the accessibility methodology and accessibility planning programme.

Chapter 20 includes the technical references used to inform this research

13 Travel time distribution

13.1 Introduction

Travel time is a necessary but not a totally sufficient condition for access to be achieved. Even so, starting with travel time analysis helps to identify locations with or without access for further analysis of cost, safety, quality and other variables affecting access to be considered later.

The number of people willing to make a journey to a destination generally decreases as the length of the journey increases; it also changes by transportation mode and journey purpose. This effect is described as deterrence to travel. In transport planning deterrence is modelled using *deterrence functions*; these are mathematical models that have been fitted to travel data derived from surveys. The accessibility of an activity decreases as the cumulative deterrence of reaching the activity increases. Therefore, determining deterrence functions is an important first step in developing any accessibility model.

The deterrence function is often conveniently represented in transport planning with a *negative exponential* (decay) function since this can be calibrated to fit observed travel behaviour using the form:

$$f(t) = e^{-\lambda t}$$

where λ is a constant that defines the slope of the decay curve. The tails of these types of curves often need to be curtailed to fit observed behaviour because there are observed maximum travel time thresholds and practical minimum travel time thresholds that need to be applied to all journeys to represent real travel choices.

Other curve fitting methods can be applied, which may provide a better fit to the observed trip-making data for travel time but are not as widely used and are much more computationally intensive. De Vries et al (2004) identified that logistic decay functions provide the best fit when modelling travel costs, particularly for intermediate distances where commuting behaviour is highly elastic. The *weighted logistic decay* function follows the form:

$$f(t) = \frac{1 + e^{-\alpha\beta}}{1 + e^{\beta(t-\alpha)}}$$

where α defines the t value of maximum change and β is a shape-fitting parameter.

However, the logistic decay function cannot easily be fit to data in common software packages such as Microsoft Office Excel, nor is the formulation widely enough applied in transport planning that there is a body of parameters available for comparison with other countries. For these reasons the exponential decay curve formulation has been selected for this research. Henceforth in this report λ is termed the *travel time distribution* parameter.

λ parameters for walking, cycling, bus and private motor vehicle were developed by analysing data from the NZHTS. A description of the NZHTS, as extracted from the NZTA website, is presented in appendix C.

The NZHTS provides the best overall source of travel pattern data within New Zealand. Given the national coverage and size of the NZHTS, it is assumed participants in the NZHTS have a level of access to activities and spatial separation from activities that is representative of the entire population on average. The NZHTS data therefore provides a sound basis for developing a national methodology for measuring accessibility.

This chapter is separated into three subsections:

1 The methodology used to determine the value of λ parameters

2 The results of the analysis

3 A discussion of the results.

13.2 Methodology

This section details how λ parameters were determined for the following modes of transport:

- walking
- cycling
- vehicle driver and vehicle passenger
- public transport: bus and rail.

13.2.1 Travel classification

A trip leg is a section of travel by single mode with no stops. The relevant NZHTS variables used for calculating λ values were respondent age, travel mode, trip duration, trip origin activity and trip destination activity. Survey weightings and a person response status filter were applied to all trips within the analysis. λ values were calculated for major transportation modes in main urban areas (MUA), secondary urban areas (SUA) and rural areas (RA). A full definition of these areas is provided in appendix C. Given the New Zealand accessibility methodology calculates accessibility for travel from home, only home-based trips (trips which originated at the home) were included in the analysis (the use of a folded matrix, ie trip from destination to home was not included). The MoT conditions of use stipulate that analysis of travel trends for a subset of the data may only be undertaken when the sample size of the subset is over 120 trip legs or 60 persons.

The analysis of travel time includes multiple legs with each part of the trip chains using several modes although the travel has a single primary purpose. Travel time analysis can also be applied to trip chaining where trips of different trip purposes are joined, such as shopping on the way home from work. Consequently, the travel times are made up of walking elements within journeys, direct transfers between public transport services and indirect transfers requiring walking trips between public transport services. These are all counted as part of the trip. This captures the real time involved when selecting a mode or travel, rather than just the time by the primary mode of travel. The difference is likely to be significant for public transport services, where walk times at either end of the trip and between services may add significantly to the overall trip duration, but will also account for the effects of parking supply where a longer walk trip may be required. Only trips of more than 100m were captured, as the NZHTS does not gather information for walking trips of less than this distance.

λ values were calculated for travel to eight destination types; three of which were directly drawn from the NZHTS, while education trips were classified into approximate groupings based upon respondent age. A further category was created to capture trips for *other* purposes while some activities, determined to be less useful for this analysis, were not used. The survey activity classifications and new activity designations are outlined in table 13.1. Travel to a*ll purposes* by mode is also calculated, as a combination of all the categories from table 13.1 that were used in the new activity designations. When considering chained trips for multiple purposes there is usually a dominant trip purpose and linked trip purposes. In these circumstances it is assumed the characteristics of the trip are most influenced by the dominant trip purpose.

Table 13.1 Main data categories and descriptions in NHTS

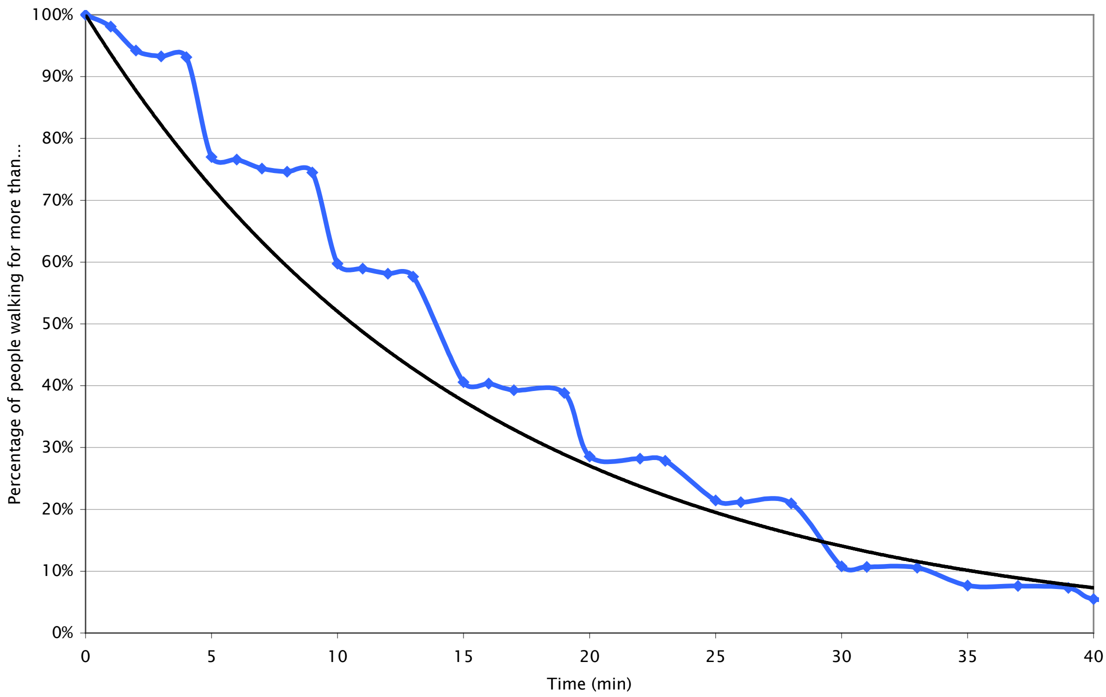
NZHTS activity description	New activity designation(s)
Home	n/a *(is origin for all trips)*
Work – main job	Employment
Work – other job	Employment
Work – employer's business	n/a
Education	Primary school Intermediate school High school Tertiary education
Shopping	Shopping
Social welfare	Other
Personal business/services	Other
Medical/dental	Other
Social visits	Other
Recreational	Recreational
Change mode	n/a
Accompany someone else	n/a
Left country	n/a
Other	n/a
Overnight Lodgings	n/a

13.2.2 Calculating travel time distribution parameters

Travel-time distribution parameters are calculated by fitting the negative exponential trend line to the cumulative distribution function of surveyed travel times. Exponential trend lines can be fitted by many software packages, including Microsoft Office Excel, which enables a visual display of the results and easy calculation of R^2 values[8]. Values presented in this report have been calculated using a least squares approximation, part of the Numerical Python computing environment and accessed through the Python programming language. The deterrence function is only calculated based upon the first 95% of data, as attempting to fit sparsely placed higher values can severely distort the resulting curve. An example of walking to home-based employment in MUAs is shown in figure 13.1; in this case the λ parameter is shown to be 0.065

[8] However, Microsoft Office Excel calculates the R^8 value of an exponential curve incorrectly (presenting the proportion of variation in ln(y) that can be explained by x instead of the proportion of variation in y that is explained by x), in some cases this will grossly overestimate or underestimate the value. All R^8 values presented in this report have been calculated correctly from first principles.

Figure 13.1 MUA employment (home-based) walking travel time distribution function



The raw data (distribution of trip times) shown in figure 14.1 highlights an apparent categorisation of trip times by NZHTS respondents. It reveals the majority of NZHTS respondents have rounded their trip duration to the nearest five minutes, eg 'my trip took 15 minutes' rather than accurately recording the trip time to the nearest minute. Accurate recording of trip duration to the nearest minute would reveal a smoother distribution of trip times more akin to the negative exponential trend line fitted to the data.

13.3 Results

13.3.1 Summary of λ parameters

To conform to the conditions of use specified by the MoT, three levels of sample validity are defined and are highlighted in the following tables of travel time distribution results. Conditions specify that trends can only be established from data samples containing more than 120 trip legs or 60 persons. As this analysis combines multiple trip legs into trip chains, a secondary limit of 90 trip chains has been proposed when identifying insufficient sample sizes. The three levels of validity displayed in the following tables are:

1 **Valid.** Curves fit to data containing more than 120 trip legs and more than 90 trip chains.

2 **Indicative.** Curves fit to data containing fewer than 120 trip legs but more than 90 trip chains; indicated by underlined type.

3 **Provided only for reference.** Curves fit to data containing fewer than 120 trip legs and fewer than 90 trip chains; indicated by ***boldface italic underlined*** type.

The final two categories contravene the MoT conditions of use and should only be used for reference, in conjunction with other sources of information[9] or in the context of other results presented in this research

[9] For example, the λ parameters developed by the Department for Transport (DfT) from the UK National Travel Survey.

that feature an adequate sample size. Blank cells in the following tables indicate there were either no samples or an insufficient number of samples for a trend to be developed.

λ parameters for the assessed activities, categorised by area types, for walking and cycling travel are summarised in table 13.2. λ parameters for travel as vehicle driver and vehicle passenger are displayed in table 13.3, while those for local public transport are shown in 13.4. The λ parameter determines the rate of decay of the curve. A small λ parameter has a lesser rate of decay than a large λ parameter; hence, fewer short duration trips and a greater proportion of longer duration trips.

Table 13.2 Walking and cycling λ parameters

Destination activity	Walking						Cycling					
	MUA		SUA		RA		MUA		SUA		RA	
	λ	R^2	λ	R^2	λ	R^2	λ	R^2	λ	R^2	λ	R^2
Employment	0.065	0.93	***0.069***	***0.91***	0.144	0.91	0.060	0.82	***0.084***	***0.82***	***0.047***	***0.75***
Primary school	0.101	0.89	***0.119***	***0.74***	0.147	0.79	***0.094***	***0.62***	***0.119***	***0.90***	***0.146***	***0.79***
Intermediate school	0.077	0.93	***0.056***	***0.76***	***0.110***	***0.86***	***0.085***	***0.78***			***0.142***	***0.76***
High school	0.057	0.84	***0.056***	***0.88***	***0.076***	***0.81***	***0.073***	***0.78***	***0.106***	***0.87***	***0.087***	***0.99***
Tertiary education	0.061	0.68			***0.100***	***0.86***	***0.081***	***0.87***				
Shopping	0.100	0.96	0.080	0.91	0.097	0.97	0.122	0.87	***0.168***	***0.59***	***0.151***	***0.78***
Other	0.092	0.98	0.089	0.93	0.144	0.96	0.090	0.95	***0.104***	***0.72***	0.088	0.93
Recreation	0.066	0.94	0.066	0.86	0.063	0.96	0.053	0.96	***0.047***	***0.98***	0.046	0.97
All activities	0.077	0.97	0.074	0.93	0.090	0.98	0.069	0.94	0.080	0.89	0.065	0.95

Table 14.3 Vehicle driver and vehicle passenger λ parameters

Destination activity	Vehicle driver						Vehicle passenger					
	MUA		SUA		RA		MUA		SUA		RA	
	λ	R^2	λ	R^2	λ	R2	λ	R^2	λ	R^2	λ	R^2
Employment	0.068	0.88	0.086	0.95	0.064	0.98	0.071	0.87	0.063	0.95	0.049	0.97
Primary school							0.118	0.92	0.180	0.71	0.117	0.93
Intermediate school							0.101	0.90	***0.267***	***0.43***	0.129	0.94
High school	0.067	0.83			***0.066***	***0.73***	0.087	0.89	***0.137***	***0.85***	0.088	0.95
Tertiary education	0.063	0.90	***0.110***	***0.87***	0.060	0.97	0.052	0.92			***0.044***	***0.94***
Shopping	0.119	0.92	0.166	0.90	0.072	0.98	0.095	0.92	0.130	0.90	0.044	0.98
Other	0.079	0.96	0.118	0.94	0.059	0.96	0.074	0.96	0.066	0.78	0.053	0.97
Recreation	0.073	0.95	0.089	0.94	0.060	0.98	0.065	0.96	0.047	0.70	0.039	0.96
All activities	0.080	0.94	0.104	0.95	0.064	0.98	0.080	0.095	0.075	0.87	0.053	0.97

Table 13.4 Local public transport, bus and rail, λ parameters

Destination activity	Local bus						Local rail					
	MUA		SUA		RA		MUA		SUA		RA	
	λ	R^2	λ	R^2	λ	R2	λ	R^2	λ	R^2	λ	R^2
Employment	0.036	0.70			***0.012***	***0.75***	***0.019***	***0.59***				
Primary school	***0.060***	***0.87***			0.047	0.69						
Intermediate school	***0.039***	***0.65***			***0.041***	***0.42***						
High school	0.034	0.51	***0.046***	***0.30***	0.036	0.74						
Tertiary education	0.027	0.62										
Shopping	0.037	0.79										
Other	0.036	0.78			***0.042***	***0.63***						
Recreation	***0.036***	***0.63***										
All activities	0.037	0.76	***0.061***	***0.66***	0.041	0.76	***0.021***	***0.67***				

13.4 Discussion

13.4.1 Comparison of cycling λ parameters

The cycling λ parameters derived for New Zealand were compared with similar parameters developed in the UK, by the Department for Transport (DfT), which used the UK National Travel Survey to calculate cycling deterrence parameters for various trip purposes. A generic comparison of the λ parameters can be made for several trip purposes between UK and New Zealand MUAs, as shown in table 13.5. The table shows λ parameters for cycling in New Zealand are consistently lower than the UK values for the range of trip purposes shown. This suggests there are more short-duration cycling trips made in the UK and a greater proportion of longer duration cycling trips made in New Zealand.

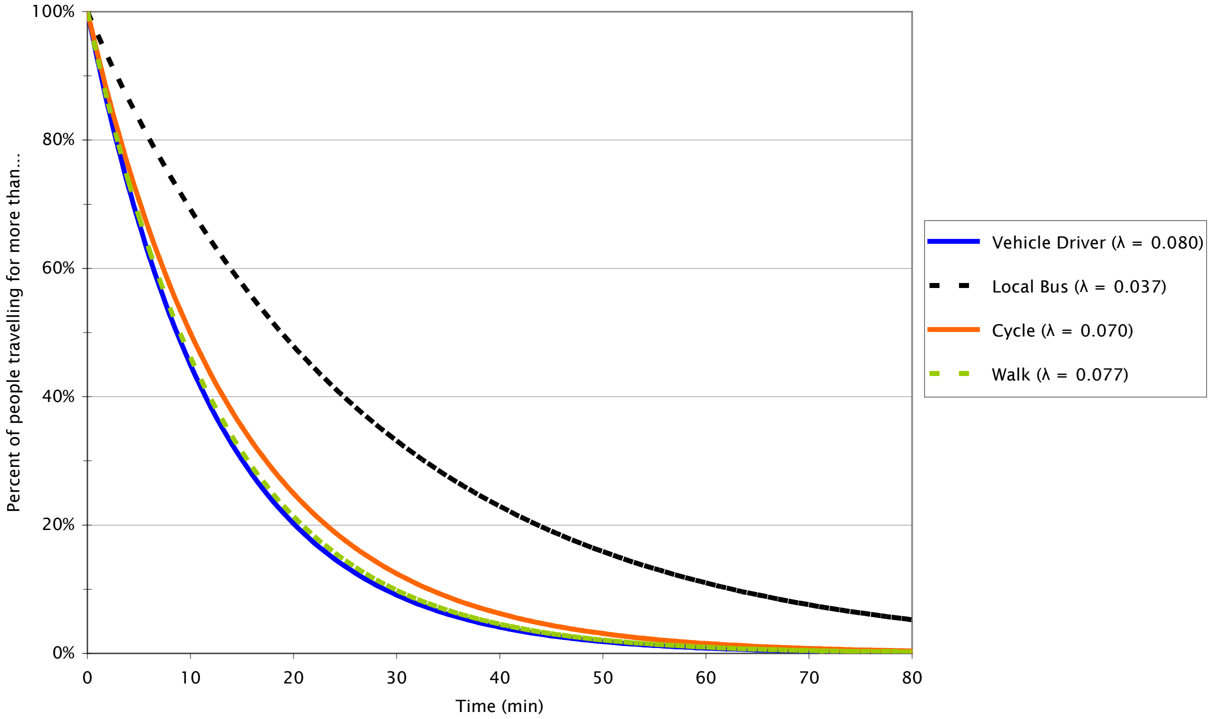
Table 13.5 Cycling λ parameters – UK/New Zealand comparison

UK		**New Zealand (MUA)**	
Destination type	**λ**	**Destination type**	**λ**
Secondary education	0.101	High school	0.073
Further education ALL	0.095	Tertiary education	0.081
Work ALL	0.091	Employment	0.060

13.4.2 Travel time distribution by mode

A comparison of the λ parameters for all activities for each transportation mode is shown in figure 13.2. It can be seen that the λ parameters are similar for journeys made by walking, cycling and private motor vehicle. However, the λ parameter for travel by bus is significantly lower. This indicates a greater proportion of trips made by public transport are of longer duration than the other modes, and perhaps more importantly, relatively few short duration trips are made by public transport compared with other modes.

Figure 13.2 Travel time distribution to all activities in MUAs



13.4.3 Future model development

As noted in the introduction to this section, logistic decay functions provide a better fit to the surveyed data than negative exponential functions. Recent work in this area by Abley Transportation Consultants has resulted in the development of a methodology for fitting logistic decay functions to the NZHTS survey data. A significant improvement in the ability to fit the data over the negative exponential function was observed, as similarly noted by other researchers. However, it was not possible to update the entire accessibility model within the timeframe of this research. Work has since been undertaken to include the logistic decay functions into the New Zealand accessibility model methodology.

14 Network creation

This section describes the creation of the four transportation networks that are required as inputs to the calculation of the comprehensive accessibility scores. The four networks are the private vehicle, cycling, walking and public transport networks.

The private vehicle network was generated from street centreline data. It forms the basis of the cycling network and was used to generate a base walking network, which underwent refinement to become a walking network. The walking network was used as a base to create the public transport network. Spatial and temporal availability of public transport was then added to this network. It should be noted the public transport network developed for this project includes only bus services; however, the methodology used could also be applied to rail and ferry services.

Due to the staged construction of the networks, where each successive network was built on those previously created, it is recommended they be developed in the order presented in this chapter.

14.1 Private vehicle network

The private vehicle network was the simplest of all the transportation networks to create. Starting with a GIS layer of road centreline locations, the appropriate attributes were set in order to model the travel of private vehicles through the road network.

Firstly a field was added to hold the length of each edge (road segment) in the network. Then this field was populated using the GIS to measure the length of each network edge.

Each edge in the network was then attributed with a ‘best estimate’ of the average travelling speed based on the road hierarchy. The average speeds selected for the model of the Christchurch private vehicle network are shown in table 14.1.

Table 14.1 Modelled speeds for the Christchurch private vehicle network

Road type	Modelled speed (km/hr)
Private road	20
Local road	30
Collector	30
Minor arterial	40
Major arterial	40
Motorway	70

The average speeds applied to each edge in the network should be based on actual or modelled values when that information is available. For example in the UK the accessibility indicators use the same data sets that are used in dynamic driver information systems. From GPS systems in cars and the speed of travel of mobile phone networks along each road link there are now comprehensive data sets available showing the speed of travel of vehicles on most road links. Only very lightly trafficked roads do not currently have associated speed measurements. GIS systems like Google and Bing Maps now show live traffic speeds and the data can also be purchased for accessibility modelling. In the UK, DfT has purchased data for the calculation of accessibility indicators since 2009. The speeds at which vehicles travel through networks can also be established from survey data using number plate recognition systems and this can be used to calibrate average speeds for different categories of vehicle.

Other useful information to assist with allocating correct speeds to each road link includes information such as delay at intersections and link speeds, which can often be extracted from traditional traffic assignment models. When the estimation is based on a categorised system, such as the road hierarchy or speed limit, a reduction factor should be applied to account for the effects of delays generated by intersections, congestion and traffic management devices. Further application of this technique could include areas such as slow or congestion zones where slower network speeds are evident such as in a city centre.

Finally a field was added to the network dataset to hold the calculated traversal time for each edge. This was measured in seconds and was calculated from the length of the edge in metres and the traversal speed in km/h as follows:

Edge traversal time (s) = edge length (m)/edge traversal speed (m/s)

Where it was necessary to model one-way streets, an attribute was added to the dataset to record if the edge was traversable in the direction it was digitised, opposite to the direction of digitising or in both directions. This attribute enabled modelling of one-way restrictions on travel across the network.

14.2 Cycling network

Cyclists make use of the road network in order to complete their journey. They can use roads both with and without marked cycle lanes, but are excluded from motorways. In addition to the use of the road network, cyclists also make use of off-road cycle paths and alleyways which have the potential to shorten trip distances and therefore travel times. The road network is used as a starting point for the creation of the cycling network.

Aerial photography and maps of off-road cycle paths were used to assist in the digitisation of the locations of off-road cycle paths in order to add them to the cycling network. Once the off-road cycling links were manually digitised, the cycling network model underwent a sensibility review, to ensure all known off-road cycle paths had been correctly added.

The speed for cycling along flat sections of the cycling network was set to 20km/h, to represent a cyclist of reasonable fitness. This speed was then adjusted according to the average gradient of each of the edges in the cycling network. The speeds were varied up to 30km/h when travelling downhill, and reduced to 10km/h when travelling uphill. These speeds are slightly higher than the cycling speeds in the UK, and hills in New Zealand also have a lower impact on speeds than in the UK. The UK analysis has recognised that this is an area of work requiring further research.

Table 14.2 describes the relationship used to relate slope gradient to the modelled speed in the cycling network.

Table 14.2 Look-up table to relate edge traversal speeds in the cycling network to the edge's gradient (vertical distance/horizontal distance)

Minimum gradient	Maximum gradient	Modelled speed (km/h)
< -0.05	-0.05	10
-0.05	-0.03	15
-0.03	0.03	20
0.03	0.05	25
0.05	> 0.05	30

Given the off-road cycling links had been added to a copy of the road network, the appropriate fields for edge length and edge traversal time already existed.

The GIS was again used to calculate the edge length in metres. The traversal time and edge traversal speed fields were removed and the following fields were added: TF_gradient, TF_speed, FT_speed, TF_seconds, FT_seconds (note: FT = from-to, TF = to-from, this relates to the direction in which the network edge was digitised).

First, the elevation of the endpoints of each edge on the network was calculated using a digital elevation model (DEM). From this, the gradient of each edge was calculated in the direction in which the edge was digitised and the result stored in the TF_gradient field.

Then using the relationship described in table 14.2, the speeds along the network edges were updated.

Once the speeds had been calculated, the edge traversal speeds in the direction of digitisation (TF) and the direction reverse to digitisation (FT) were calculated, using the following relationship:

Edge traversal time TF (s) = edge length (m)/edge traversal speed TF(m/s)

Edge traversal time FT (s) = edge length (m)/edge traversal speed FT(m/s)

14.3 Walking network

The walking network differs from the road network as it includes network edges where pedestrians can use links that are not alongside roads. This includes walking paths through conservation areas, parks, schools and other off-road short cuts frequently taken by pedestrians.

First, a base walking network was created from street centreline data using an automated process (described in section 14.3.1). Once the base walking network was developed, careful editing was undertaken to improve the resolution of the model, adding off-road walking links and increasing the level of detail in areas such as the CBD and suburban centres that have high pedestrian traffic volumes (refer to section 14.3.2).

14.3.1 Base network

The creation of the citywide walking network was achieved by using a wide variety of data from different sources and combining elements of this data to form a single GIS layer (Williams 2008).

The data which was collected and used to create a walking network for Christchurch for this project is shown in table 14.3

Table 14.3 Data sources used to create a Christchurch citywide walking network

Data	Details	Source
Road centreline	Contains road hierarchy and other detailed information related to each road	Christchurch City Council
Aerial photographs of Christchurch city	Most recent aerial photographs, taken in January 2007. Pixel size 0.125m	Christchurch City Council
Bus route	2006 metro bus routes.	Environment Canterbury, Christchurch City Council
Bus stop	2006 metro bus stops.	Environment Canterbury, Christchurch City Council
Open space zones	Most of the parks and reserves in Christchurch set aside primarily for recreation. Defined in the 'Christchurch city plan, volume 3, part 6'.	Christchurch City Council, city GIS layer

Data	Details	Source
Conservation zones	Areas within the city of scenic, ecological, or heritage significance. Defined in the Christchurch city plan, volume 3, part 5'.	Christchurch City Council, city GIS layer
Cultural zones	A range of sites predominantly associated with a range of metropolitan and local facilities of a cultural, recreational, educational, research, artistic or heritage character. Defined in the 'Christchurch city plan, volume 3, part 7'.	Christchurch City Council, city GIS layer
Traffic signals	Plans for each set of traffic signals operative in Christchurch including phasing and pedestrian links.	Christchurch City Council
Zebra crossings	Locations of zebra crossings.	Abley Transportation Consultants Limited
District centres and business retail parks	Based on Business 2 (B2) and Business Retail Park (BRP) zones as defined in the 'Christchurch city plan, volume 3, part 3'.	Christchurch City Council district plan

14.3.2 Data manipulation overview

The first step in creating the citywide walking network was to create a base walking network as shown in figure 14.1. The base walking network was created using road centreline data (part 1 of figure 14.1). All road centrelines that ran through rural land, mostly on the outskirts of a city, were omitted from the process as it is unlikely pedestrians would use a rural road for commuting or for access to public transport. In addition to this, rural roads do not generally provide pedestrian facilities such as footpaths. It is the existence of a formed footpath that defined if a walking link was created, ie walking on the road did not meet the walking quality threshold for the provision of a walking link.

In order to best represent the location of footpaths at a citywide scale, a buffer was created around each road link using the road hierarchy to estimate road width (part 2a of figure 14.1). The relationship between road width and hierarchy for the Christchurch walking network was obtained from the *Christchurch city plan* (Road hierarchy standards, volume 3: part 8, appendix 2).

The buffer polygons were converted into polylines and then planarised in ArcGIS to ensure connectivity (part 3 of figure 14.1). The planarise tool in ArcGIS splits and connects all line feature segments together by creating intersections at all points where paths originally crossed but did not intersect. Planarising has the effect of reducing complex 3D networks or unstructured linear data into simple, fully connected 2D networks. These line segments became the basis for the creation of the footpath and road crossing network edges.

Figure 14.2 displays an example of the Christchurch base walking network layer on top of an aerial photograph.

Figure 14.1 Steps Involved in creating the base walking network

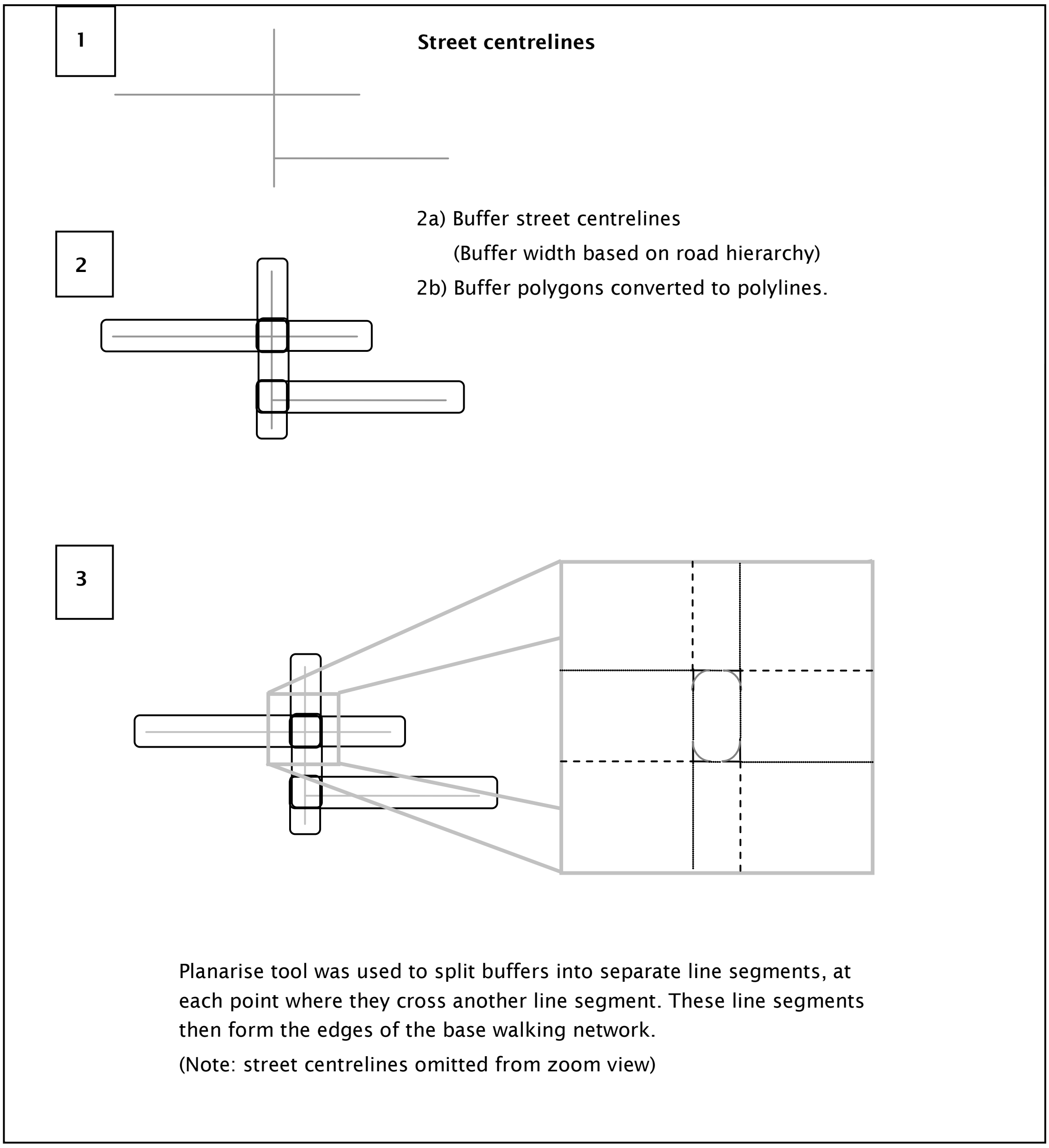


Figure 14.2 Base walking network – Riccarton, Christchurch city

Two attribute fields were created for the walking network edges. One defined the link type and another defined road crossing or intersection type for links that crossed roads.

Links that crossed the road were identified by intersecting the network edges with the original street centreline dataset to identify which edges crossed the road centreline. Each walking link in the base network was identified with a type attribute of FOOTPATH. Link type and intersection attribute values used in the walking network are detailed in appendix D.

14.3.3 Improving the base network

The walking network in district centres and business retail parks as defined by the *Christchurch city plan* (Christchurch City Council 2005) was edited manually using aerial photographs as a guide in order to achieve an increased level of accuracy. This included the addition of off-road walking links and the removal of edges from the base walking network, where the aerial photograph indicated no formed footpath existed.

The base walking network within the district centres and business retail parks was deleted and recreated manually as the base network did not provide an acceptable level of quality. Each walking link within a district centre or business retail park was identified with a type attribute of CARPARK, CARPARK_PUBLIC or OPEN AIR MALL in accordance with the link type. Only outdoor walking links were recorded in the walking network.

Road crossing links within district centres or business retail parks were also digitised manually from aerial photos and these links were given the value ROAD for the intersection attribute. The attribute for the street name of a road crossing is the street name of the road that is being crossed, not the street which runs parallel to the road crossing.

The locations of zebra crossing links were added to the GIS city-wide walking network GIS layer and confirmed using aerial photographs. Each zebra crossing link was given the intersection attribute ZEBRA.

Intersections that included traffic signals were recorded on the walking network. These intersections were deleted from the base network and re-created using aerial photos. This was especially important where intersections used a combination of traffic lights, traffic islands and pedestrian crossings. Traffic signal intersection links were assigned with an intersection attribute of LIGHTS.

Data from the Christchurch City Council included information regarding the traffic signals location, identification number and phasing (the order vehicular and pedestrian traffic is allowed to move). It also indicated which road crossings at the intersection allowed for dedicated pedestrian movement. Once the intersection was identified, the aerial photograph covering the area was used to ensure accuracy of data editing and input of the related links. Each crossing link was given a percentage value based on the frequency the crossing was available for pedestrians to cross. This percentage information is recorded in the PERCENTAGE attribute field of the walking network.

Walking links that were not along public roads, and therefore not included on the base network, were coded using a combination of aerial photographs and land-zoning data from three categories outlined in table 14.4.

Table 14.4 Land-zoning data

Zone type	Zone name	Description
Open space zones	Open space 1 zone	Small areas of public open space which are of value to local neighbourhoods and communities
	Open space 2 zone	Large areas of public open space for active recreation which serve a suburban or district-wide function
	Open space 3 zone	Large public recreation areas, may be associated with areas of open parkland
Conservation zones	Conservation 2 zone	Public parks of city-wide significance which help provide the city with its unique scenery and character
	Conservation 4 zone	Most of the cemeteries which are currently operating. Other cemeteries that have significant heritage value are zoned in conservation 2 to provide greater recognition of their historic values
Cultural zones	Cultural 4 zone	Campuses of tertiary education facilities

For each walking link running through one of these six zones mentioned above, the code was assigned to the 'type' attribute. For example, a walking link running through Hagley Park was assigned 'O2', as Hagley Park is zoned 'open space 2'. This later enabled the turning 'on' or 'off' of specific links depending on the accessibility analysis being undertaken.

Bus routes in the city were used in conjunction with aerial photographs to identify pedestrian refuges in high-priority locations. Each bus route was inspected to ensure all pedestrian refuges along it were located. The network links running through the pedestrian refuges were manually coded with the intersection attribute of REFUGE and added to the citywide walking network layer.

A particular feature that affects people's propensity to walk is the presence or absence of streetlights on links for walking during the hours of darkness. In the UK it has been found that some households have very poor access during the hours of darkness due to the inability to travel along unlit streets during the hours of darkness. Any feature such as this can be added to the walking network model by marking a link as inaccessible during particular time windows. Time windows become particularly important when looking at walking links to public transport and the inability of safe walking links can be a critical barrier to access.

14.3.4 Assigning road crossing delays

Once the attribution of the walking network was complete, the delays incurred when using the relevant links to cross the road were calculated for the entire network data set. The time to cross the road was calculated based on the delay incurred while waiting for a gap in the traffic, plus the time required to walk across the road. Table 14.5 shows the approach used to determine the average delay encountered before beginning to cross the road.

Table 14.5 Logic used to assign road crossing delays to the walking network

Crossing facility	Attribute code	Delay calculation method	Rationale
None (not at intersection)	ROAD + hierarchy attribute	Tanners extended model applied to the full road width	Must cross multiple lanes of traffic at once in order to complete crossing.
None(at intersection crossing minor leg)	ROAD + hierarchy attribute	2 seconds	Confirmation delay to ensure no traffic is coming.
Pedestrian refuge	REFUGE	2 * [Tanners extended model applied to half the road width]	Refuge reduces the crossing distance so a gap is only needed in one stream of traffic at a time.
Traffic signals	LIGHTS	½ * (100% – [Percentage of traffic signal cycle available to pedestrians]) * [total traffic signal cycle time]	Pedestrians only allowed to cross for part of the traffic signal cycle. Assumes pedestrian arrives at signal half way through the unavailable period.
Pedestrian crossing	ZEBRA	2 seconds	Confirmation delay to ensure traffic has stopped.
Roundabouts	(not coded)		Treated as none (at intersection crossing minor leg) or pedestrian refuge

Tanner's (1962) extended model was used to model the road crossing delays when crossing arterial roads and roads with pedestrian refuges. Tanner's extended model takes into account a host of variables including traffic volumes, crossing width, number of lanes to be crossed and bunching of vehicles. The traffic volumes and number of lanes were estimated from the road hierarchy information, while the crossing width was calculated directly in the GIS from the length of the network edges. The proportion of bunched vehicles was assumed to be constant.

The delays calculated using the methods listed in table 14.5 were capped at two minutes, on the basis that after this period of time a person was likely to use less safe methods to utilise any crossing opportunity for roads less than or equal to a minor arterial. For higher-order roads, pedestrians were modelled to divert to the nearest 'safe' crossing point.

14.3.5 Editing tips

An essential practice when manually entering or editing spatial data for a connected network is to use the 'snapping' tool. The snapping tool snaps feature end points to other feature end points when the mouse cursor enters the 'snapping range' of the specified destination point. Snapping ensures topological connectivity of the network. All spatial network data was entered and edited using the snapping tool.

An extra precaution taken when entering and editing the walking network, in addition to snapping all features, was to also slightly overlap crossing links on the base walking network, then planarise the edits. This method ensured if an intersection or road crossing link was not correctly snapped to the base network, then the link overlapping the base network would always connect by creating an intersection at the point of overlap.

14.3.6 Areas for future refinement

A higher level of detail could be achieved by not only breaking walking links at intersections, but every time the type of pedestrian facility changed. Examples of this would include the addition of driveway crossings, commercial driveway crossings, street crossings other than main intersections and areas along roads where there were no footpaths as it was reasonable to assume pedestrians walked along these areas at different speeds than they would along a formed footpath.

District centres and business retail parks have higher pedestrian traffic volume flows than other suburban footpaths and provide important facilities for the community such as shopping, healthcare and community services. Pedestrians in these areas often use buildings, especially indoor shopping malls as thoroughfares and the addition of these to the walking network would also increase the detail of the walking network and increase the accuracy of subsequent analysis.

The development of a detailed walking network is a labour intensive process. A balance must be struck between the level of detail captured in the network and amount of time invested.

Therefore the time intensive improvements to the base walking network were only carried out for centres of high pedestrian activity in the first instance. As various study sites are examined in more detail, the level of detail of the walking network around these sites should also be increased. This will incrementally improve the quality of the walking network used in subsequent analyses.

14.4 Public transport network

A trip on the public transport network involves walking to the bus stop, travelling on the bus to the bus stop closest to your destination, and then walking to your final destination. It may also include transferring to another bus, or other modes of public transport such as ferries and trains. The following description refers to creating a public transport network for buses, although a similar approach is applicable for other modes.

The public transport network model was constructed using the following information:

- walking network
- location of bus stops

- location of bus routes
- bus frequency details
- bus stopping details (which bus stops are used by which bus routes).

With the exception of air bridges in the CBD, everything in the walking network is on the same (conceptual) grade or level. This means whenever two edges on the network cross, a person can transfer from one to the other, ie they can move from one footpath to another wherever they meet. This is not the case with public transport. It is not always possible to transfer between buses wherever their routes cross. Instead one must travel to the nearest bus stop, alight the first bus, wait for the next bus to arrive and then continue one's journey on the second bus.

In order to enforce this logic, each bus route was added to the network dataset on a separate level. This meant the different bus routes passed over each other without connecting which enforced the requirement to stay on the bus between stops.

To model the activity of boarding and alighting a bus at a bus stop, connecting links were drawn between the walking network (on level 1) and each bus route (on different levels) that stopped at that bus stop to pick up or drop off passengers.

A schematic diagram of the public transport network is illustrated in figure 14.3, showing the walking network on level 1 and each bus route on successive levels. Links were then made between the walking network on level 1 and the relevant levels for the bus routes which stopped at that location.

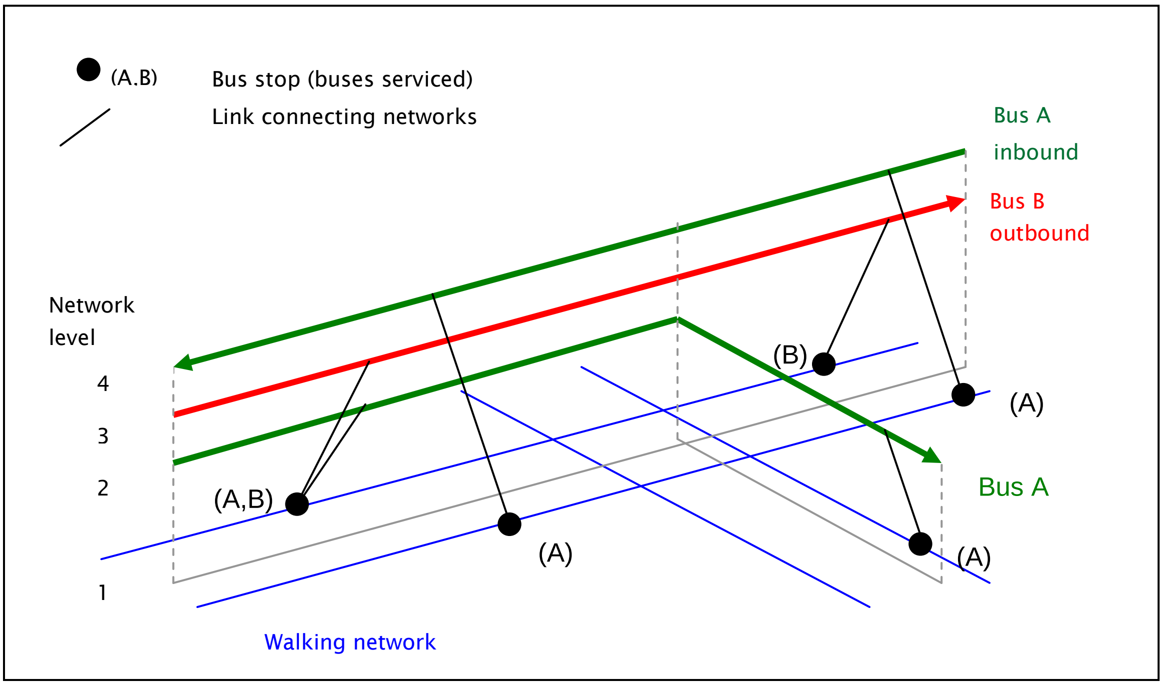
These links for boarding the bus were attributed with a delay to model the time spent waiting for a bus to arrive. This value was set at half the timetabled frequency of the bus or a maximum of 7.5 minutes.[10]

The value was capped at 7.5 minutes (450 seconds) on the basis a passenger would not leave their house for the bus stop until close to the anticipated time for the bus to arrive. No delay was assigned to these links for alighting the bus. All of these connecting links were digitised in the same direction, ie from the walking network to the bus route. This meant the delay could be applied to just one column in the table, ie it only needed to be added to the (FT) digitised direction and not the reverse (TF) direction.

Note: if a bus turned around at the end of its route with passengers still onboard, a single link was required to connect the levels of the inbound and outbound bus routes.

[10] This compares with a minimum of 10 minutes set in the UK accessibility indicators for any journey that involved boarding a bus.

Figure 14.3 Schematic diagram of the public transport network



Each edge of the network included the speed at which it was possible to travel along that edge (path) stored as an attribute of the edge. For the edges which were part of the walking network and the links for boarding and alighting public transport, this speed was set to an average walking speed of 1.3m per second. This speed should be varied depending on the ability of the target user being assessed, ie slower speeds should be applied for less able users and faster speeds for more able or purposeful users (such as commuters).

For the edges which formed part of a bus route, the average speed of the bus along the bus route was calculated from the scheduled timetable. An average speed was calculated based on the travel time between stops recorded on the timetable and the distance along the bus route between these two stops. This average speed was then applied to all the edges that comprised that section of the bus route. This was repeated for the entire length of each bus route in the public transport network model.

In the UK it has been observed that bus timetables are not regular throughout the day. It is very common for express buses to offer a 20-minute journey in peak hours to a town centre and for the rest of the day take more than twice this time for the same journey. Therefore the question arises whether the journey time used in the accessibility modelling should be 20 minutes or 40+ minutes. Between 2006 and 2009 the UK analysis assumed a median journey time of six modelled time periods but this proved to be unstable so since 2009, 23 modelled time periods have been used and a probabilistic method is used to calculate the journey time based on the probability of a journey time being chosen. Shoppers for example might choose to travel at a time when a faster journey time is available but people travelling to health appointments have less choice of journey time so the journey time is an average of fast and slow speeds. Some travel needs are largely made off peak, such as attending evening education classes, so would be constrained to slower journey times.

The New Zealand public transport timetable data should allow a similar sort of approach but undertaking 23 model runs for each trip purpose and then averaging the results is a substantial task involving considerable resources.

The cost of travelling along an edge in the network was modelled as the time (in seconds) taken to traverse the edge. For the edges on the walking network, while onboard a bus and when alighting a bus, this cost was calculated as:

Edge traversal time = edge length/edge traversal speed

When boarding a bus, the delay due to waiting for the bus to arrive was added to the edge traversal time to give the following equation:

Edge traversal time = (edge length/edge traversal speed) + waiting delay

The edge traversal time in seconds was then stored in a field called 'Seconds' and used to perform travel time calculations across the public transport network.

14.5 Possible network refinements

All the networks were originally constructed in a flat 2D plane. Over the majority of Christchurch, this generalisation is not unrealistic. However in the Port Hills, errors between the slope distance and the 2-D plan distance begin to appear. To overcome this error, the network edge length should be set to the slope distance to improve the accuracy of the models.

Due to time constraints the effect of gradient on network traversal speed was only incorporated into the non-motorised networks (walking and cycling) where this effect would have the greatest impact.

All the above networks have been created based on time. The use of cost, either real or perceived are variables that would be useful for testing including public transport fares, penalties for public transport interchange and car parking charges.

15 Accessibility calculation methodology

15.1 Overview

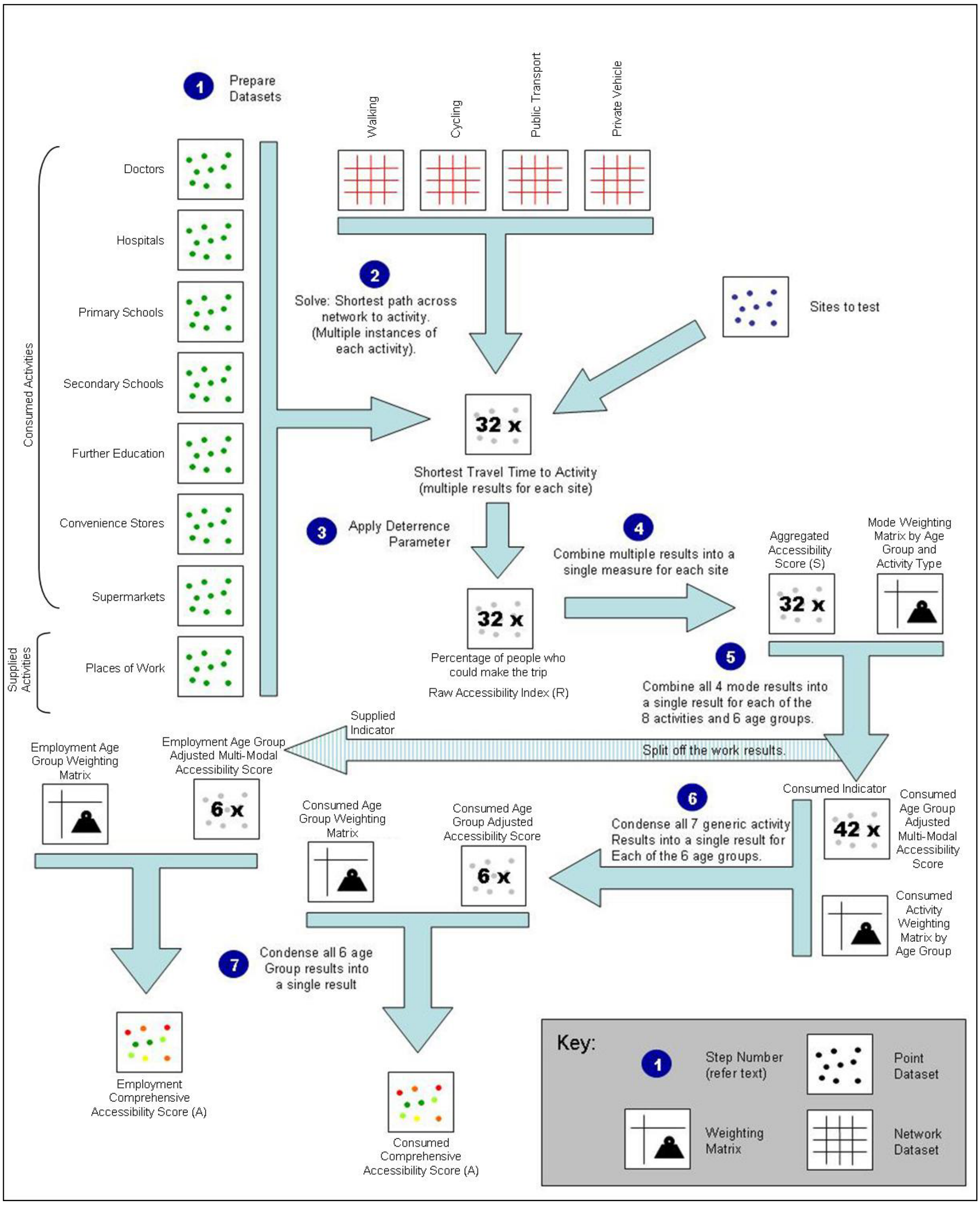
The accessibility calculation methodology described in this report can be broken down into seven steps as shown in figure 15.1, forming two distinct phases. The first is a network analysis (steps 1–4) and the second involves aggregating the results of the network analysis to produce the final comprehensive accessibility score (steps 5–7). Steps 1–4 are useful whether or not there is a clear accessibility policy to back them up. The travel time results generated can be used by policy makers and planners in many different ways as shown in the UK. In contrast steps 5–7 require the scores to have some meaning in policy. This is like the German or Netherlands approaches where accessibility goals are specified in policy and then measuring techniques are used to support the management and monitoring of progress towards the goal.

The first phase involves the preparation of the input datasets, interrogating the network dataset to find the quickest path(s) from the site being assessed to as many destinations of the activity type under consideration that are within the 95% percentile travel range. A series of raw accessibility indices are created for the site. The raw accessibility indices (R) are combined to create the aggregated accessibility score for the site. These steps are repeated for each of eight activity types and four transportation modes. This generates 32 datasets which are then aggregated in phase 2 (refer figure 15.1, steps 1–4).

The second phase takes these 32 datasets and combines them based on the relevance of the eight activity types and four transportation modes for the six different age groups. The final result from phase 2 is the comprehensive accessibility score, a single value which measures the overall accessibility to key activities from the site. The outputs of the intermediate steps in phase two yield results for accessibility to a single activity type by age group (eg accessibility to doctors for children under five) and the overall accessibility of the site to key facilities by age group (eg overall accessibility for people aged over 66) (refer figure 15.1, steps 5–7).

The following sections describe each of these seven steps in detail and explain the terms which have been introduced above.

Figure 15.1 Overview of the accessibility calculation methodology



Note: step numbers match the headings in the following sections

15.2 Step 1 – preparing the data

The accessibility calculation methodology described in this report requires four different types of input data. These are:

- location of the sites where accessibility is being tested (origins)
- location of the eight key activities (destinations)
- four network transportation models (transportation modes)
- three relative weighting matrices (importance).

15.2.1 Locations to measure accessibility

The first requirement is a point layer of the locations for which the accessibility is to be measured. These will become the origins of the shortest path analysis. The case study presented later in this report used both meshblock and land parcel centroids as locations for different iterations of the calculation.

15.2.2 Location of activities

A point layer is required for each of eight core activities that will contribute to the accessibility model. These eight activities are:

- doctors
- hospitals
- primary schools
- secondary schools
- further education
- convenience stores (dairies, petrol stations, convenience stores)
- supermarkets
- places of employment (jobs).

These eight activities are based on the six trip purposes considered most important for people's life-chances proposed by the British Government's Social Exclusion Unit (SEU 2003)[11]. The six measures have been extended, by removing a single measure for schools and dividing primary and secondary schools into separate entities as well as adding a new measure for convenience stores. The inclusion of age-based schools improves the quality of the accessibility scores calculated later. The inclusion of convenience stores includes measurement to one of the more useful accessibility tests, being accessibility to milk and other convenience goods. These eight activity types are now referred to as the core+ activities for the remainder of this report and form the destination datasets for the network calculations. Different destinations are used in different part of the UK analysis. For example in Wales 14 trip purposes are used including post offices, libraries, pubs, significant transport nodes, leisure centres and sports facilities. The eight destinations recommended by the SEU were not adopted in quite this way by DfT since the data on

[11] The report examines the links between social exclusion, transport and the location of services. It is particularly focused on access to those opportunities that have the most impact on life-chances, such as work, learning and healthcare.

shopping and leisure proved to be difficult to calibrate using any of the data sets available on floorspace and retail choice. Therefore town centres were used in 2006 as a proxy for a range of shopping and leisure facilities, and for access to friends and family and these were formally published as part of the core indicator data set from 2009.

In addition the UK analysis included many other facilities but excluded the calculation of the other indicators as funded by non-transport departments. Other facilities monitored annually include the locations of solicitors offering legal aid, county courts, crown courts, magistrates' courts, pharmacies, free cash machines, banks, building societies and petrol stations.

15.2.3 Sites of employment

Employment locations are modelled using census meshblock data. First, the meshblock polygon layers are converted to a point layer of meshblock centroids. Then total employment statistics are attached to these points. This yields a series of points across the study area representing sites of employment, which have a weighting for their significance (ie number of jobs in each meshblock).

Randomly distributing all jobs as points within meshblocks, while excluding roads and other non-employment related land uses, would yield a more realistic distribution of employment opportunities. However in a city the size of Christchurch, this would result in a dataset of ~145,000 points as opposed to ~3000 points for meshblock centroids. This would then generate up to ~142,000 extra potential paths which would need to be solved for each site for which the accessibility score is to be calculated. This would result in a large increase in processing time and for the purposes of this research would not assist the development of the accessibility model methodology. Nevertheless, for real world examples this approach may be worthwhile if combined with a Monte Carlo statistical simulation.

15.2.4 Network datasets

Four vector network datasets are required for the model, one for each of the four modes of transportation considered in the model. The creation of these networks is outlined in chapter 14 of this report.

15.2.5 Weighting matrices

In order to aggregate the outputs of the network analysis to obtain the final comprehensive accessibility score it is necessary to assign relative weightings to each of the datasets produced. Four matrices are required, which describe:

- how each mode of transportation varies with age group and activity type
- how each activity type varies by age group
- each age group as a percentage of the total population
- each working age group as a percentage of the total working population.

Not all transportation modes are appropriate for all age groups when travelling to certain land use activities. For example, the elderly are less likely to cycle due to their physical capabilities and a driver licence is only available to those over a certain age. For the purposes of developing the comprehensive accessibility score methodology, the weighting of each transportation mode when travelling to each activity type for each age group is assigned on a 'best assumed' basis to allow the methodology to be tested. In order to improve the integrity of the methodology, further research to adjust or confirm these values if the comprehensive accessibility score is deemed useful, is required.

The usefulness of a comprehensive accessibility score that aggregates more specific information is potentially limited given it smoothes out any accessibility limitations within a specific mode, activity or age group. If a purpose of accessibility modelling is to take a more disaggregate look at travel patterns, aggregating the results can disguise the findings. However an aggregate figure is also useful for showing how well transport systems provide coverage of a range of trip purpose and the components of the combined indicator can be weighted by the demand for or importance of the trip purpose for each resident. Nevertheless, it is included within this research as a potential 'headline indicator' should further research be commissioned.

The following logic was used to set up these initial weighting matrices:

- If all four modes were generally available to the age group, the relative mode weightings were set to 25% each (ie equal weighting).
- For convenience stores emphasis was given to walking and cycling modes, as the authors considered it more likely a person committed to using motorised transport would go to a supermarket that provided a higher level of service and typically a lower cost of goods.
- When visiting doctors and hospitals, physical modes of transportation were weighted lower than motorised forms due to the likelihood of illness or injury giving rise to the need for the journey.
- The under four-year-old age group relies on caregivers to accompany them when using the networks. For this reason cycling was given a reduced weighting as cycling with a small child is often considered a safety concern.
- For the 65 and older age group, a shift away from cycling was assumed in favour of walking, public transport and private vehicle, due to the physical capability of this age group. Public transport was given a greater emphasis than private vehicles as many of the older members of this age group no longer had a licence to drive and hence were no longer able to use this transportation method independently.

The fraction of the total population made up by each age group was calculated from 2006 Census data. The weighting assigned to each age group for work activities was based on the age group's fraction of the total population aged 10 years and older in the 2006 census data.

All four weighting matrices used in the accessibility calculation methodology are presented in appendix E.

15.2.6 Other tasks

When the OD point datasets are linked to the various networks to allow calculations to progress, they are snapped to the nearest network element. If the distance across which this snapping is allowed to take place is large, distant sites may be snapped to a network edge close to the location of an activity, resulting in an erroneously short travel time.

In order to limit the impact of moving the points to coincide with the network elements, the tolerance was set to a maximum of 250m, to reduce the magnitude of any errors that this might introduce.

15.3 Step 2 – solving for shortest path

The second step in the methodology involves calculating the 'cost' to travel from the measurement locations (origins) to the core+ activities (destinations), across each of the four transport mode networks.

The travel cost is modelled using travel time, rather than travel distance or real or perceived travel cost. This allows intersection delays and variable travel speeds such as walking and bus travel to be modelled in the same network and is a significant refinement on travel distance alone but other routing algorithms are available.

Of course not all route choice is based on least travel time and hence other variables such as cost would be useful to further test the accessibility results. Additionally, quality inputs such as those determined via community street reviews (Abley 2010) or via other mathematical models that predict walking quality (Abley and Turner 2011) provide an additional level of refinement. Other routing choice such as a cyclist's preference for safety over speed is another refinement for cycle routing. The Abley Cycle Route-Choice Metric (ACRM) proposed by Rendall et al (2012) is an enhancement in this area. Refer to chapter 14 for details on the construction of suitable networks.

In order to limit the processing time required to perform the network analysis, it was necessary to set a limit for the maximum allowable journey time. This maximum travel time threshold was set to the 95th percentile trip duration calculated from the NZHTS data and by rearranging the travel time frequency function for the mode in question. The rearranged equation form is shown in figure 15.2.

Figure 15.2 95th percentile travel time equation

Solving $y = e^{-\lambda t}$, for the travel time completed by less than 5% of NHTS respondents, yields:

$$0.05 = e^{-\lambda t}$$

Rearranging:

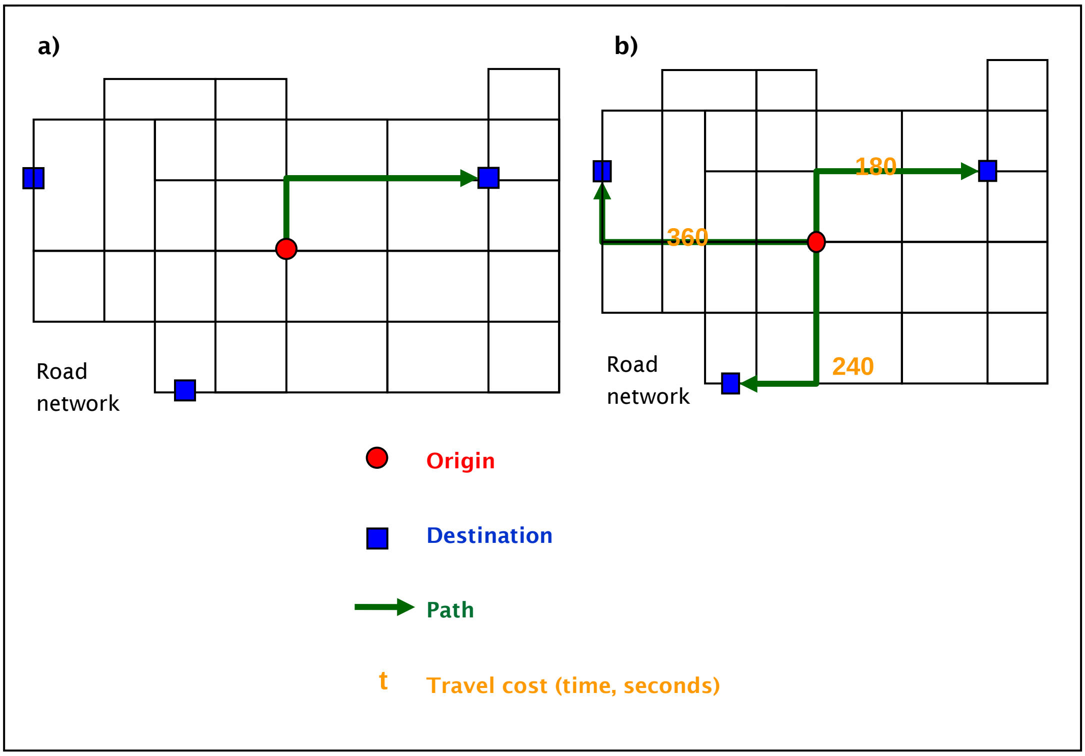
$$t = -\ln(0.05) / \lambda \qquad \text{; t = time in minutes}$$

$$t = -60 * \ln(0.05) / \lambda \qquad \text{; t = time in seconds}$$

While this approach is computationally efficient it results in a zero accessibility outcome for journeys beyond this threshold. A further enhancement of this methodology could be to calculate the travel time to the nearest destination up to a much higher threshold.

The shortest travel time path is calculated by each model to all activities that are within the maximum trip travel time (refer to figure 15.3)

Figure 15.3 Calculation of shortest travel times



a) Find the shortest path to the closest destination (in terms of travel time)

b) Calculate the shortest paths by travel time to the remaining instances of the activity type

Steps 2 to 4 of this methodology are repeated 32 times, once for each of the eight activity types and four transportation modes.

15.4 Step 3 – applying the (λ) parameters

Step 3 involves application of the negative exponential equations to calculate the 'raw accessibility indices'.

Once the series of paths was calculated from each measurement location to the multiple instances of the activity under consideration, the travel times along these paths were converted to a measure of accessibility called the 'raw accessibility index' (R). This was done by inputting the travel times into the negative exponential equations.

The raw accessibility index is described in figure 15.4.

Figure 15.4 Raw accessibility index

Travel time distribution equation: $R = e^{-\lambda t}$

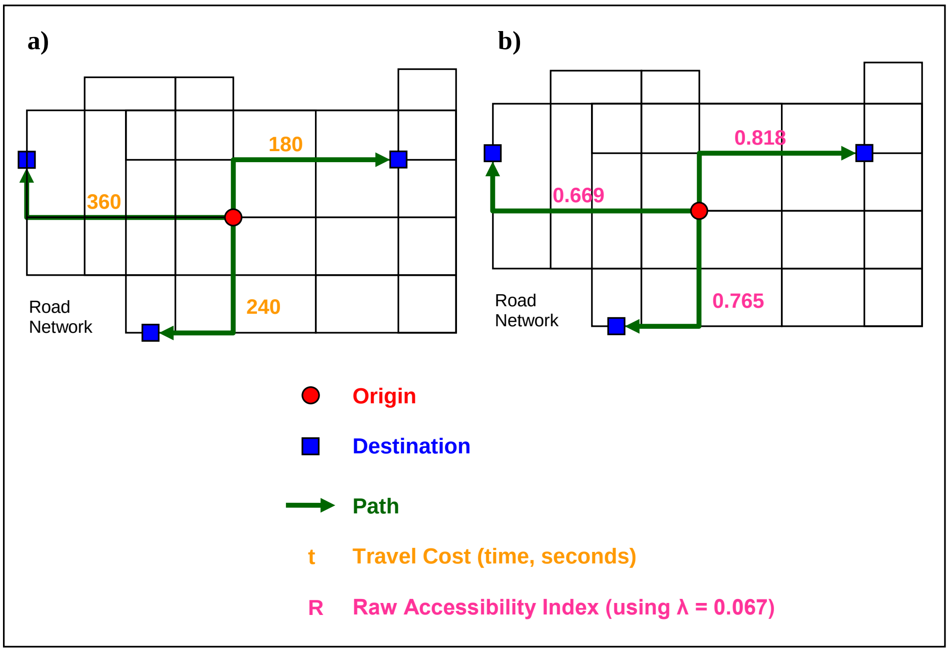
R	=	raw accessibility index (percentage of people who would make a trip of length t)
t	=	time in minutes
λ	=	travel time distribution parameter

So for t = time in seconds use: $R = e^{-\lambda (t / 60)}$

The raw accessibility index range extends from 0 to 1. A score of '1' means the destination site is immediately adjacent to the origin so has the maximum possible raw accessibility score.

This results in each measurement location having multiple raw accessibility indices, which record the percentage of people who would make the trip to each instance of the destination activity (figure 15.5).

Figure 15.5 Application of the travel time distribution equation to the series of path times



- a) using an appropriate value for λ based on the mode and activity type
- b) yields a series of values for the raw accessibility indices for the site being considered

Given the NZHTS (chapter 13) only yielded statistically significant results to allow the definition of the (λ) parameters by journey purpose for walking and private vehicle modes, the all-purpose (λ) parameters for walking, cycling, public transport and private vehicle in MUA were used in the calculation methodology (shown in table 15.1).

Table 15.1 All-purpose (λ) parameters

Transportation mode	All purpose (λ) parameters
Walking	0.077 (0.089)
Cycling	0.069 (0.072)
Public transport	0.037 (0.041)
Private vehicle	0.080 (0.078)

Note: The figures shown in brackets are the actual values used for the case study and reflect earlier derived values based on trip legs rather than the more comprehensive methodology of trip chains described in chapter 13.

15.5 Step 4 – incorporating multiple opportunities

Access is a binary measure of accessibility where an activity is either reached across a network or not. The first instance of an activity reached when searching outwards from a point provides access. Being able to reach subsequent instances of the same activity, does not improve this binary measure. However, reaching subsequent instances of the same activity does improve the opportunity for the consumer to realise the activity. The first instance of an activity provides access, subsequent instances provide choice (of services, cost etc), improving the opportunities available to the consumer of the services.

Accessibility to a choice of destinations is of value, but the extra marginal value provided by successive opportunities decreases. This is because each new choice increases the total pool of activity providers, and therefore comprises a smaller fraction of the increasing pool of choices. At some point this diminishing rate of return means the benefit gained by reaching an additional opportunity is no longer significant, effectively reaching a state of ‘saturation of opportunities’.

15.5.1 Methods considered

Four different methods to model the impact of multiple opportunities were considered during the development of the accessibility calculation methodology. The four methods for combining all the raw accessibility indices for each site into a single value were: maximum, mean, sum and the sum of a harmonic series. The advantages and disadvantages of using each of these methods are presented in table 15.2.

The result of applying these equations to a real world example shows using the straight sum or the harmonic series yields results that are logically consistent with the concept of real world accessibility. That is, access to more instances of the same activity type increases the level of service that can be achieved from that site. The use of the mean provided erroneous results where suburbs with access to low numbers of facilities scored higher, and use of the maximum value reduced the accessibility to a simple map of distance to the closest activity and ignored multiple opportunities.

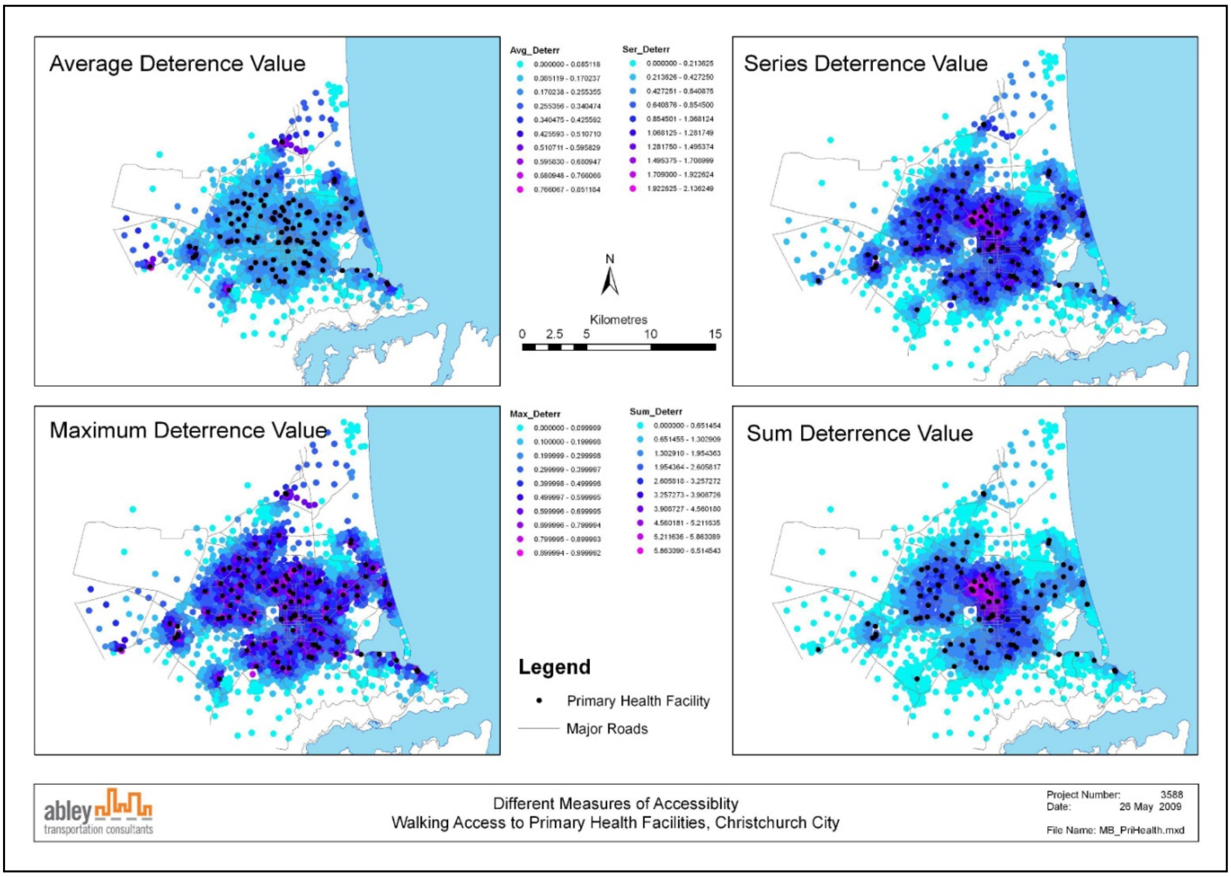
By analysing the slope of the equations used to model how the rate of return varies with each additional instance of an activity (figure 15.5), it can be seen that while both the sum and the harmonic series consider multiple opportunities, only the harmonic series recognises the diminishing value of subsequent opportunities.

Table 15.2 Summary of four different methods of accounting for multiple opportunities

Name	Formulae	Advantages	Disadvantages
Maximum	$\text{Max } R_{\text{Opportunities}}$	• Only first destination counts • Measures best opportunity • Percentage measure of access • Simple to interpret, percentage of people who access activity.	• Does not consider multiple opportunities. • Does not consider saturation of opportunity.
Mean	$(\sum_{1}^{n} R_i) / n$ n = number of accessible opportunities	• All destinations count • Measures overall opportunity in travel range • Simple to interpret, percentage of people who find activity pool accessible.	• Distant opportunities dilute score of closer opportunities. • Does not consider saturation of opportunity.
Sum	$\sum_{1}^{n} R_n$ n = number of accessible opportunities	• All destinations count • Measures overall opportunity in travel range • Closer opportunities not diluted • Can be used when sites are of unequal value. • Simple to interpret, measure of accessible activity equivalents.	• Does not consider saturation of opportunities.
Harmonic series	$\sum_{1}^{n} (R_i / n)$ n = rank accessible opportunities	• All destinations count • Measures overall opportunity in travel range • Closer opportunities not diluted • Additional opportunities have lesser value (saturation of opportunity) • Simple to interpret, measure of accessible activity equivalents.	• The decay of value of successive opportunities cannot be fairly applied when the value of each instance of the activity is not equal.

Note: the mean, sum and harmonic series all consider multiple opportunities, but only the harmonic series accounts for the concept of the saturation of opportunity.

Figure 15.6 The four different methods of considering multiple opportunities to access an activity, illustrated using access to primary health facilities over the walking network in Christchurch

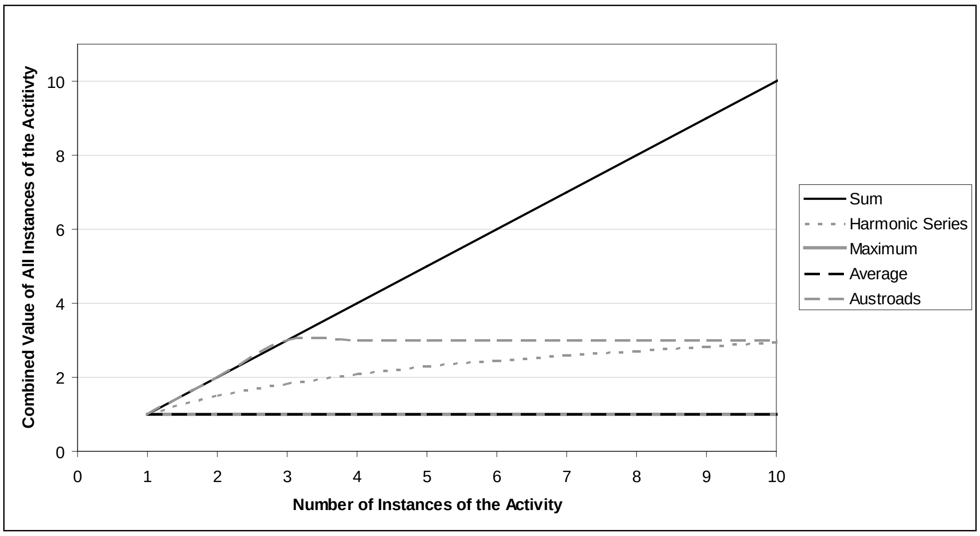


The following points are noted regarding the four methods:

- Taking the average value only reports high values when close to a single instance of the activity (the purple values in the outer suburbs), providing an erroneous picture of accessibility. See figure 15.6 upper left quadrant.
- The maximum value method can be seen to reduce the measure of accessibility to a simple contour map of distance to nearest activity. See figure 15.6 lower left quadrant.
- Both the sum and the sum of a harmonic series of (λ) parameters illustrate access to more opportunities improves accessibility. This can be seen in the pink areas around the central city, as the centre of the city is the optimum place to minimise overall travel distance to the pool of primary health facilities distributed around the city. See figure 15.6 upper and lower right quadrants.
- The sum of a harmonic series of (λ) parameters also accounts for the saturation of opportunity. This is illustrated by the peak in the central city that is moderated, while the majority of the outer suburbs have mid-range values (in many cases similar to the CBD). Highlighting the additional benefit gained by reaching the 4th, 5th, 6th doctor (for example) is of far less importance than the benefit provided by being able to choose between, say, the first three practitioners. See figure 15.6 upper right quadrant. A harmonic series is the same as a sum log function; which economic theory shows is the correct form for utility order competition.

If the origin and destination were co-located the travel distance would be zero and the raw accessibility index would yield a value of 1 (or 100%). With this assumption in mind, it is possible to compare the four methods that were considered for modelling the change in benefit provided by each additional instance of an activity as shown in figure 15.7.

Figure 15.7 Comparison of methods considered for modelling multiple opportunity



For the maximum and average methods, there is no increase in benefit to be gained from accessing further instances of the activity. In fact with the average method, without the assumption of co-location, the distant values would lower the score of closer values.

The sum can be seen to weight each additional opportunity equally, while the harmonic series shows a decreasing benefit gained by each additional activity, thereby replicating the concept of a saturation of opportunities. It should be noted the harmonic series diverges as the number of opportunities increases but this rate of increase diminishes, ie the closest activity score is not scaled, while the second closest activity adds only half its score and the third adds only one third of its score and so on.

The above methods were compared with the modified isochronic measure proposed in the Austroads report on the development of accessibility measures (Espada and Luk 2009). The Austroads report assumed a saturation level of three opportunities. The modified isochronic measure accounts for the saturation of opportunities, but assumes that below the threshold value, all instances of an activity are of equal value and once the threshold is reached, additional instances provide no further benefit. In comparison, the harmonic series also accounts for the saturation of opportunities but factors in the concept that the greatest benefit comes from the closest activity, with a decreasing benefit gained by each successive opportunity.

The measurement of the 'saturation of opportunities' requires more in depth analysis where it may be possible to determine the actual values and the apportionment of value of each additional destination. This is an area of further research. Additionally it should also be noted that opportunity saturation probably changes over time as expectations grow for access to a larger range and choice of opportunities. Therefore saturation is a relative term. However the concept is still useful since an additional convenience store may provide very limited additional benefit as might the tenth and eleventh primary schools.

In the UK, the origin indicators publish the scale of the opportunity accessible from a location in terms of floor space, number of jobs or number of facilities (eg post offices). The value placed on the level of additional choice then becomes a matter for the user of the analysis results rather than a decision by the analyst. Until further research has been undertaken in New Zealand to ensure accurate representation of choices a similar approach to the UK could be adopted. Seven of the eight core+ activities are activities that are consumed and can be considered to be provided homogenously, and each instance of the activity is just as valuable as any other, ie the level of service provided to a consumer by Doctor A will be the same as the service provided by Doctors B and C, or that an equivalent range of items is provided by all supermarkets. These activities are named consumed activities.

Places of employment are considered differently because employment is supplied by an individual. An individual would not be qualified or able to fill all the employment opportunities within a city, therefore the level of service provided by these places of employment is not equal. This means the closest employment opportunity reached (in this instance in travel time), may not be realisable for a specific individual. This is a significant difference between the activities consumed and supplied by an individual.

15.5.2 Consumed activities

Activities that have a homogenous level of service between each instance of an activity are termed consumed activities. The seven core+ activities considered to be consumed are:

- doctors
- hospitals
- primary schools
- secondary schools
- further education
- convenience stores
- supermarkets.

For these activities the (λ) parameters for each path were added using a harmonic series. This weights each additional instance of an opportunity less than those preceding it, accounting for the decreasing value of each instance of an activity as the size of the pool of providers to choose from increases. The value of the indicator is a number greater than zero if accessibility exists. A value of 1 shows a high degree of connection between the origin and destination showing they are effectively co-located adjacent to the origin. This does not necessarily mean the activity is co-located, rather it may mean that two, three or more activities are closely located, which in equivalent terms means the activity is 'next to' the origin.

A score of zero means no access and a score of one is the equivalent of one destination located next door. Having only one destination with a score of 0.9 is equivalent to a choice three equidistant destinations each with scores of 0.5. The score can exceed one, but in practice rarely exceeds about three.

15.5.3 Supplied activities

Activities that have a special level of service between each instance of an activity are heterogeneous and termed supplied activities. The ability to realise the activity varies substantially between each instance of the activity. 'Places of employment' is the only core+ activity identified as meeting this criterion.

Weighting the accessibility score similar to the consumed activities based on the order in which supplied activities are reached (using a harmonic series) is not appropriate in this instance. Instead, it is preferable to total the number of (co-located equivalent) positions within an acceptable travel range to determine the accessibility to employment. Therefore, for places of employment, the (λ) parameters for each path are summed to provide the accessibility measure. The value of the indicator is then an ever-increasing value that recognises that saturation of opportunities is not reached.

It is not possible to compare the consumed and supplied activities because although the basis for the calculations is the same, the way they consider multiple opportunities and saturation of opportunities is significantly different. For this reason it is also not possible to include both the supplied and consumed elements for an aggregated indicator. Combining the supplied and consumed indicators to one aggregated score requires further research including reviewing the way supplied activities are measured and possible saturation values.

15.5.4 Modelling places of employment

The number of employment places in a location can be obtained from census information. It is then possible to randomly distribute points within mesh blocks to represent each of the employment opportunities. The travel time across the network to each of these points can then be calculated. Repeating this process with multiple iterations of the random distribution (Monte Carlo simulation) would yield a statistically robust result.

However, the computational power and time required to calculate such a result for a city the size of Christchurch rapidly expands to prohibitive levels. For example, there are approximately 145,000 jobs in Christchurch, which could mean a potential network calculation of up to 3000 * 145,000 = 435 million calculations. Conversely, by modelling places of employment at the centroids of mesh blocks they reside within, the maximum potential calculations can be reduced to 3000 * 3000 = 9 million calculations. This is achieved by solving the network path cost to the meshblock centroid, applying the negative exponential equation to the path cost and then multiplying this result by the number of jobs in the meshblock. Taking the sum of all these values yields the number of accessible co-located job equivalents.

15.6 Step 5 – age group adjusted multi-modal accessibility score

Once the network analysis phase of the methodology (figure 15.1, steps 1–4) and the 32 datasets for the aggregated accessibility score(s) (one result for each of the eight core+ activities using each of the four transportation modes) is completed, these results are combined into a composite indicator titled an age group multi-modal accessibility score.

The first step of this data collation phase involves combining the four mode aggregated accessibility scores into a single multi-modal score for each of the eight core+ activities.

The relative importance of each transportation mode varies with the age of the individual and the purpose/activity of the trip. To model this, a weighting matrix was developed to describe the relative mode weightings for travel to each activity type by each age group. The development of the weighting matrix is described in section 15.2.5 and the weighting matrix is provided in appendix E.

The chosen age groups loosely relate to the following stages of life: pre-school, primary school, secondary school, further education/starting work, working and post-work. These age groups have been adjusted slightly to align with the five-year age groups of the Statistics New Zealand census data to facilitate later demographic analysis.

The six age groups used were:

- 0–4 years – pre-school
- 5–9 years – primary school
- 10–19 years – secondary school
- 20–24 years – further education/starting work
- 25–64 years – work
- 65 years and older – post-work.

The following equation describes how each aggregated accessibility score (S) was multiplied by its relative mode weighting (between 0.00 and 1.00) and then summed for all four transportation modes.

This equation was applied once for each of the six age groups, combining the four mode results into a single multi-modal result for each activity type. This resulted in 48 datasets (six age groups * eight activities * one multi-modal dataset).

$$M_{Age\ Group} = \sum_{1}^{k} S_k \cdot AgeGroupModeWeight_k$$

k = number of modes considered

The resulting value $M_{Age\ Group}$ is the age group adjusted multi-modal accessibility score and is separated into two parts. One part is the employment age group adjusted multi-modal accessibility score, and the other is the consumed age group adjusted multi-modal accessibility score.

15.7 Step 6 –age group adjusted composite accessibility score

As previously discussed, places of employment, being a supplied service are fundamentally different from the other activities that are consumed. This means the accessibility indicator for each of these activities is not comparable. Therefore step 6, which combines the results from the various activities is only performed on the seven consumed activities.

To reduce the 42 results for the consumed activities into a set of six consumed age group adjusted composite accessibility scores, the different age group adjusted multi-modal scores were merged together. This was done in a similar manner to the previous step, but this time a weighting matrix that described the relative importance of each activity type to the specific age group was used. This weighting matrix is provided in appendix E.

This is described mathematically by the following equation:

$$C_{AgeGroup} = \sum_{1}^{i} M_i \cdot AgeGroupActivityWeight_i$$

i = number of activity types

This equation is applied once for each of the six age groups, combining the seven consumed activity results into a single composite activity result for each age group. This generates six datasets, one for each age group.

The resulting value $C_{Age\ Group}$ is named the consumed age group adjusted composite accessibility score.

15.8 Step 7 – comprehensive accessibility score

The final step in the process involves combining each of the six age group composite accessibility scores into a single value that measures the overall accessibility for the site.

This is performed separately for places of employment and the seven consumed activities, forming an employment and consumed comprehensive accessibility score respectively.

Two more weighting matrices are used to weight the scores from each of the age groups when aggregating the values into the respective comprehensive accessibility scores (A).

For the generic activities the weighting apportioned to each of the six age groups is set to the age group's proportion of the national population at the time of the most recent census (2006). For places of employment, the population is weighted based on its fraction of the population aged 10 and over (to represent the working population). The population counts from the 2006 Census and their proportions are presented in table 15.3.

Table 15.3 Age group weightings from 2006 Census data

Age group	National population count (2006 Census*)	Weighting (generic facilities)	Weighting (places of employment)
0–4	275,079	0.07	0.00#
5–9	286,488	0.07	0.00#
10–19	606,207	0.15	0.18
20–24	270,978	0.07	0.08
25–64	2,093,589	0.52	0.60
Over 65	495,606	0.12	0.14
Total	**4,027,947**	**1.00**	**1.00**

The weightings applied to each age group (right column) were calculated based on each age groups population (middle column) as a percentage of the total population (or working population – approximated as those aged in the 10–19-year age bracket and over.

#Age group outside those considered to contain working age individuals.

*2006 Census data, Statistics New Zealand (2007)

This weighting matrix was used with the six age group composite accessibility scores in the following equation to generate the respective comprehensive accessibility score (A). This score calculates the overall accessibility of the seven consumed core+ activities from the measurement location to form the consumed comprehensive accessibility score.

$$A = \sum_{1}^{j} C_j \cdot AgeGroupWeight_j$$

j = number of age groups

Using the same equation, but substituting the weightings for places of employment (shown in table 15.3) yielded the employment comprehensive accessibility score.

16 Case study

The accessibility calculation methodology described in the previous chapter was tested by measuring accessibility to different activities from meshblock centroids in the Christchurch city urban area in 2009. It is important to emphasise the case study was undertaken before the devastating Canterbury earthquakes of September 2010 and February 2011.

The calculations were performed using ESRI's ArcGIS 9.3 with the Network Analyst extension. All the calculations required in the methodology were implemented using Python 2.5 and the ArcGIS Geoprocessor. This allowed the calculations to be performed outside of the ArcGIS Graphical User Interface, conserving system memory resources.

Due to out-of-memory issues when running Network Analyst, the meshblock centroids data set was separated into a series of subsets. These subsets were then processed one at a time. Once all the meshblock centroids subsets had been processed, the results were merged into a single result layer. By using the Python scripting language to create and call a sub-process to perform each iteration of the network calculations, the calculator was forced to release the memory so that it was available for use in the next iteration.

The sources of the datasets used in the Christchurch city case study are listed in table 16.1.

Table 16.1 Data sources used in the Christchurch city case study

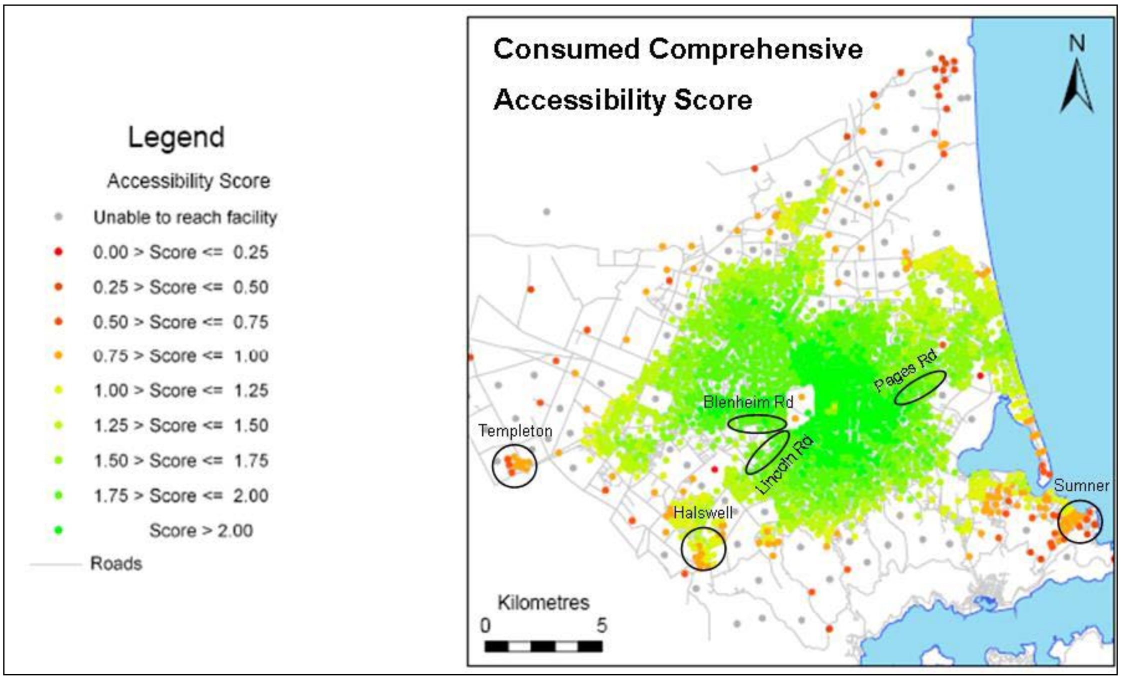
	Dataset	Source
Destinations	Doctors	Ministry of Health
	Hospitals	Ministry of Health
	Primary schools	Shapefile of Ministry of Education data – Koordinates.com
	Secondary schools	Shapefile of Ministry of Education data – Koordinates.com
	Further education	Geocoded by Abley Transportation Consultants Ltd
	Convenience stores	Zenbu.co.nz GeoHealth Lab - University of Canterbury
	Supermarkets	Zenbu.co.nz – verified against supermarket websites
	Places of employment	Meshblock centroids, with weighting based on number of available jobs. Statistics New Zealand 2006 Census data
Origins	Sites to measure	Meshblock centroids – Derived from Statistics New Zealand 2006 Census data Land parcel centroids – Derived from Christchurch City Council cadastral data
Networks	Walking network	Abley Transportation Consultants Ltd
	Cycling network	Abley Transportation Consultants Ltd
	Public transport network	Abley Transportation Consultants Ltd
	Private vehicle network	Abley Transportation Consultants Ltd

16.1 Outputs

The final output from the accessibility calculation methodology case study was a series of maps that show the spatial variation in accessibility across the Christchurch urban area, by age group, activity type and transportation mode.

The two summary outputs were the maps of the consumed comprehensive accessibility score (figure 16.1) and the employment comprehensive accessibility score (figure 16.2). A full series of graphical outputs from the model are included in appendix F1.

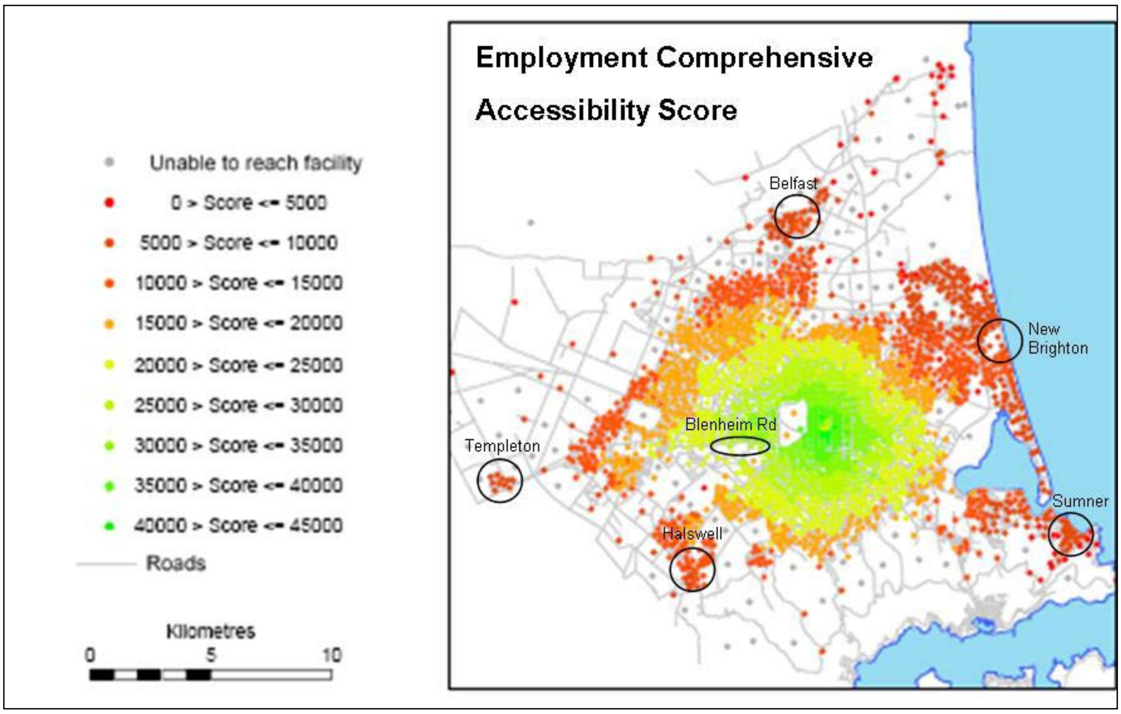
Figure 16.1 Consumed comprehensive accessibility score, Christchurch city



Accessibility to the consumed activities is greatest in the central city and decreases as the distance from the centre of the city increases. Spokes of higher accessibility can be seen radiating from the centre along the major arterial routes of Blenheim, Pages and Lincoln Roads. It also highlights the lowest (non-rural) levels of accessibility occur in the outer suburbs of Sumner, Halswell and Templeton.

Accessibility decreases in the immediate centre of the CBD due to the network model excluding private vehicles from Cathedral Square. This prevents access for these central meshblock centroids to the private vehicle network, reducing their calculated accessibility score.

Figure 16.2 Employment comprehensive accessibility score, Christchurch city



The accessibility to places of employment in Christchurch city (figure 16.2) is strongly centred around the CBD, with a noticeable ridge of accessibility extending down the commercial/industrial Blenheim road corridor and another ridge of higher employment between Memorial and Harewood avenues, due to the presence of the airport, the technology park on Sir William Pickering Drive and Northlands in Papanui. The alignment of these ridges of higher accessibility is also influenced by the alignment of major arterial roads which make it easier to commute from these areas to other parts of the city, especially the CBD.

The distant residential suburbs of New Brighton, Sumner, Templeton, Halswell and Belfast have lower levels of accessibility to places of employment due to the increase in commuting distances compared with the rest of the city.

16.2 Sensitivity testing

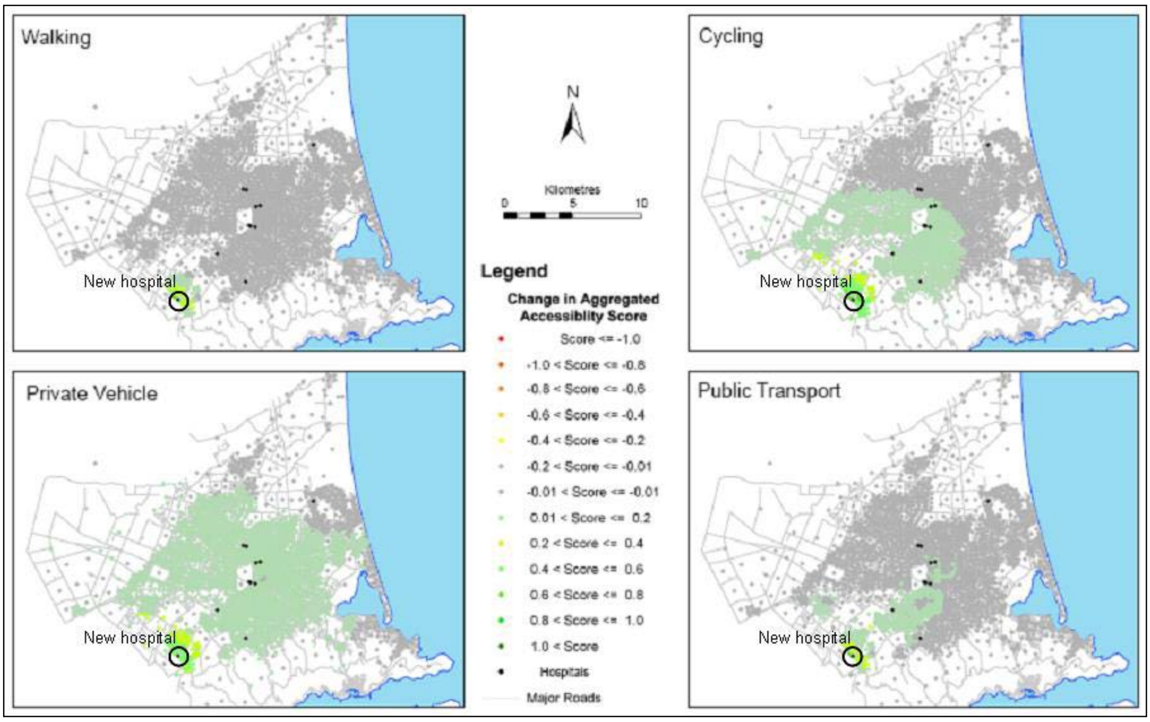
Two scenarios were examined to test the sensitivity of the accessibility calculation methodology to changes in activity provision and modifications to the transportation network design.

16.2.1 Changes in activity distribution

In order to test the sensitivity of the methodology to changes in the spatial distribution of activities, the Christchurch-based meshblock calculations were re-run, with a hypothetical new hospital added on the rural fringe of Halswell (on rural zoned land on Halswell Junction Road, opposite the T-junction with Nicholls Road).

The four results for each transportation mode for the hospital activity are presented in figure 16.3 and the impact this has on the final accessibility result is presented in figure 16.4. The full results of the model run are presented in appendix F2.

Figure 16.3 Modelled change in accessibility (aggregated accessibility score) to hospitals by transportation mode, for a new hospital in western Halswell

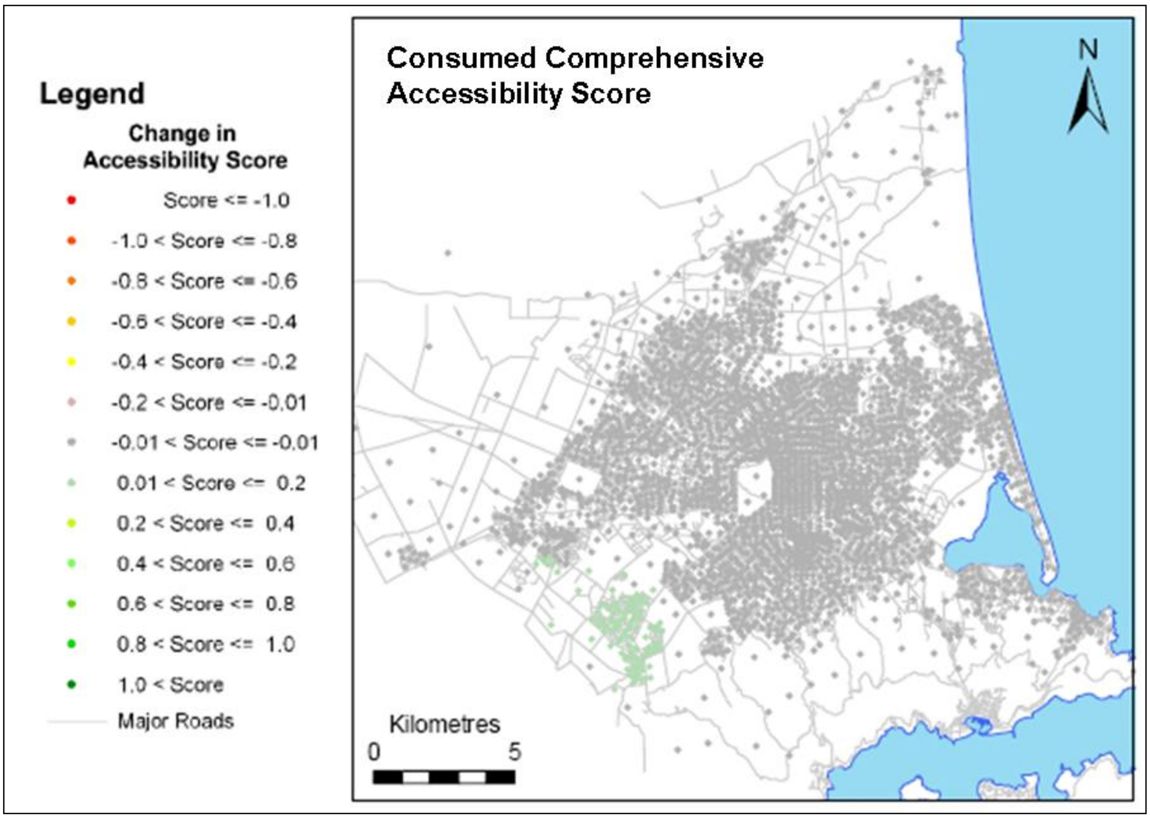


From figure 16.3 the sensitivity of the model to a new land use can be discerned. As would be expected, the impact on walking accessibility is only experienced close to the location of the change (Halswell). Access by cycling shows a radial distribution from the site of the new hospital with the strongest positive change in cycle accessibility closest to the new hospital. This is to be expected as the area around Halswell is flat and a constant cycling speed of 20km/h is assumed on flat terrain. Private vehicle accessibility also shows a radial pattern of impact with the greatest effect along arterial transportation routes that provide fast vehicle speeds.

The largest magnitude of change >0.80 is found in the walking network around Halswell as this region previously had no walking access to a hospital. More muted improvements in the aggregated accessibility score (0.4–0.6) are found for the other modes of transportation as some level of accessibility to hospitals was already realisable in this area before the addition of the new hospital.

Given the public transportation network models journeys starting on the walking network before transferring to the bus, the maximum accessibility gain is similar to that of the walking network, where the meshblock centroids closest to the modelled location of the new hospital show the greatest gain. As expected there is an obvious ridge of improved accessibility levels aligned along the bus routes between Halswell and the central city (figure 16.3).

Figure 16.4 Modelled impact of a new hospital in western Halswell on the overall accessibility to the consumed comprehensive accessibility score



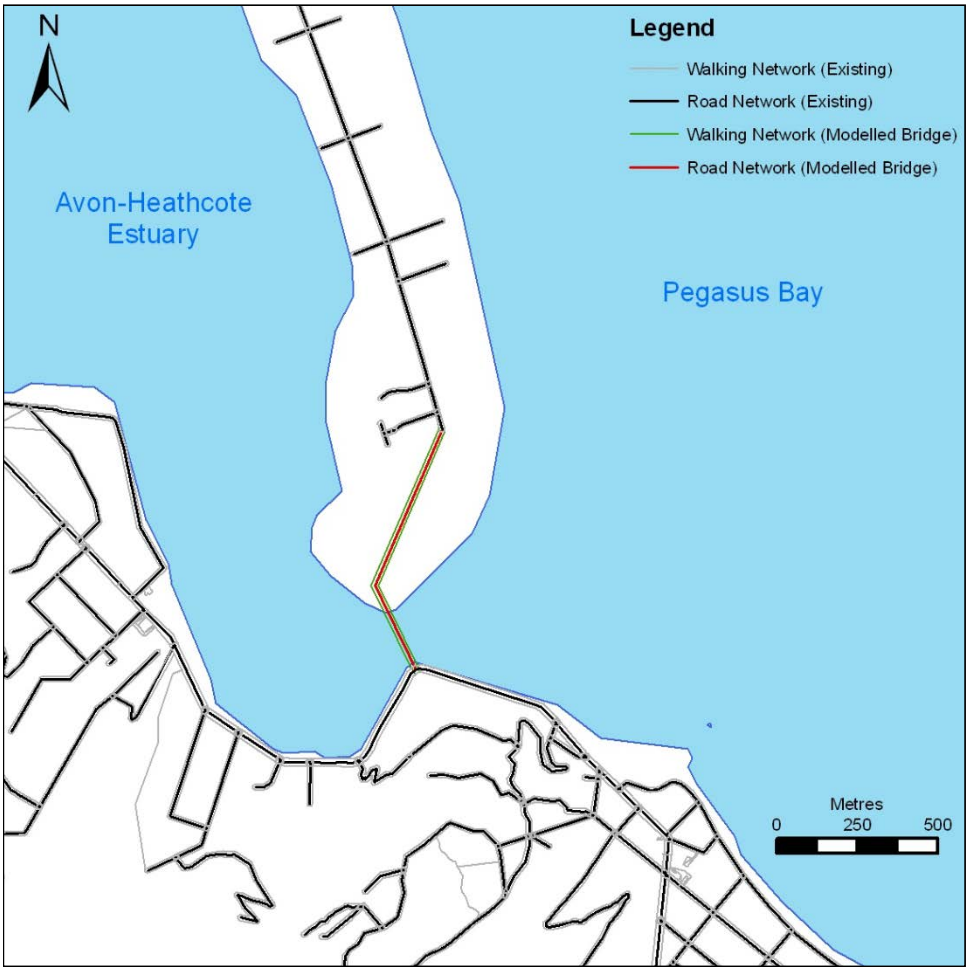
The magnitude of the average impact of the modelled change on the comprehensive accessibility score is less pronounced (positive, but < 0.20). This is to be expected as hospitals are only one of the seven activity types which are measured to arrive at the final score.

The inclusion of a new hospital shows the greatest improvement in accessibility score (+0.64) for the 0–4 years age group and the 65 years and over age group (+0.69). This is a reflection of the increased significance of hospitals (relative to other activity types) selected for these age groups. This increased significance was modelled using the weighting matrix (appendix E) that weights the relative significance of each activity type to the various age groups.

16.2.2 Modelling changes to the transport network

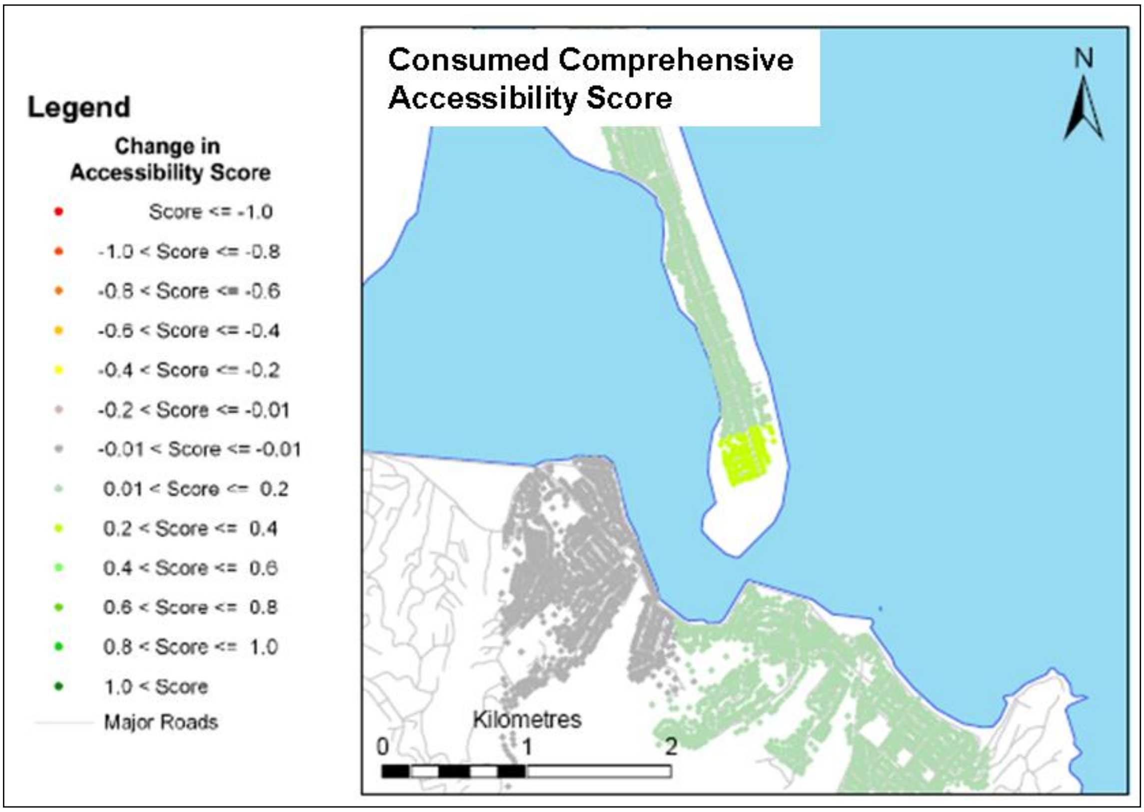
The second sensitivity test involved modelling changes to the transportation network. This was achieved by modelling a hypothetical bridge across the mouth of the Avon – Heathcote Estuary (figure 16.5).

Figure 16.5 Modelled bridge across the Avon – Heathcote Estuary



This test was performed both at meshblock level, to provide an overall picture of the city-wide impacts, and then at a higher resolution for the properties in the suburbs of South Brighton and Sumner. A summary of the change in consumed accessibility due to the bridge at the level of individual parcels is shown in figure 16.6. The full results are presented in appendix F3.

Figure 16.6 Change in accessibility due to inclusion of a bridge over the Avon – Heathcote Estuary



The results show a dramatic increase in accessibility to doctors, primary schools and supermarkets for the southern tip of the Brighton Spit with the greatest improvements for all of these being approximately 0.5. At the same time, there are some positive benefits (0.01–0.2) for the residents of Sumner.

Minor improvements (0.01–0.2) are seen for hospitals, secondary schools and further education facilities for the southern tip of Brighton Spit. This is due to the fact these facilities are already quite distant from both sides of the bridge and the magnitude of the travel time savings to these facilities due to the new bridge is minimal.

The magnitude of the change in the comprehensive accessibility score ranges between 0 and 0.4, with the maximum benefit occurring for residents on the southern tip of the Brighton Spit (figure 16.6).

17 Discussion

17.1 Key merits

This report has defined accessibility as 'the ease with which activities, either economic or social, can be reached or accessed by people'. Therefore, accessibility assessment is the measurement of how easy it is for an individual to participate in desired activities, based on a set of measurable factors, including mode and destination choice.

Accessibility is concerned with both the land use and the transport systems, and provides an integrated way of measuring changes in either system.

Measuring accessibility not only provides a more realistic representation of the transportation world (including those that may be transport disadvantaged); but accessibility also provides a better measure when considering the long-term sustainability of the transportation network. This is because unlike traditional transportation modelling that typically only models mobility using one or maybe two modes of transport (such as motorised vehicles and public transport), accessibility modelling evaluates all modes. This includes the traditional modes of transport as well as more sustainable modes of transport such as public transport, walking and cycling. Accessibility modelling also includes the various interchanges between these modes such as walk-public transport-walk, car-walk, cycle-public transport-cycle-walk and so on.

The quantification of accessibility provides:

- the ability to look at the impact of people's capabilities on the level of access they experience
- the effect of spatial factors in land use planning
- new forecasting indicators upon which decision makers can make better informed and optimum decisions
- a method to consider changes in accessibility due to changing demographics
- a method to test changes in land use, transport networks, services and destinations
- a greater level of analysis whereby those being consulted can appreciate that decision makers are considering all perspectives
- more information about how users perceive transport opportunities
- better presentation methods to show expected outcomes from recommendations.

There are five key properties that accessibility metrics should possess. The metrics derived from this research are considered to have met these criteria. These include (adapted from Davidson 2009):

- Consistency: if there is no real change in the system, then the indicator should not change. If there is real change in the system then it should change.
- Ordinality: an improvement to the system should result in a change to the indicator in a particular direction. Further improvement should result in a greater change to the indicator in the same direction.
- Linearity: in order to be properly useful in looking at trade-offs in projects, or knowing how much better one project is than another, the indicator must also be a linear measure. Linearity is required whenever indicators are to be combined.

- Meaningfulness: units should be a meaningful measure of the system being described.
- Transferability: the indicator must be able to be moved from city to town and preferably rural areas as well and still remain relevant and comparable between locations.

17.2 Understanding the outputs

The methodology presented in this report produces many results at different stages of the calculation process. These results highlight patterns of accessibility by transportation mode, activity type and age group. The subtle differences in what is being calculated and at what stage should be kept in mind when interpreting the results.

Step 2 of the methodology produces a table of travel times between each location being tested and each instance of an activity. At this stage the result is simply travel time across the network in seconds.

Applying the (λ) parameters in step 3, converts these travel times into the percentage of people who would make the journey of the calculated length (from the measurement location to the activity). It is expressed as a decimal, eg 0.25 = 25%.

17.2.1 Outputs for the consumed activities

In step 4 all the individual results for each instance of an activity that is supplied by an individual and which can be reached from a location are combined using a harmonic series. Combining all these results from step 3 can yield results over 1.00, ie >100%. In step 3, if an activity destination was co-located with the trip origin, 100% of people would be considered to make the trip. Therefore the combined result can be interpreted as **the number of co-located activity equivalents** that are accessible from the origin, ie how many equivalent activities are supplied adjacent to the origin, in order to provide an equivalent accessibility to that which is supplied by the observed distribution of destinations. This value incorporates the decrease in activity patronage as travel time increases, as well as the diminishing return from each successive opportunity.

The results from later steps in the methodology (steps 5–7) all combine the results from step 4 using a simple relative weighting method and therefore the results can be interpreted in a similar manner. Note that a value of 1.0 is an effective equivalent value to the co-located provision of one set of all measured activities.

17.2.2 Outputs for the supplied activities

In step 4, all the individual employment results are summed rather than combined using a harmonic series. This yields a count of all the employment jobs within the travel time threshold, adjusting for travel time using the negative exponential equation. This means the result can be interpreted as the number of co-located job opportunity equivalents where a value of one would be the equivalent of one home-based job. Again in the later steps (steps 5 and 7) a simple relative weighting is used to calculate the age group and overall values so the interpretation of the results is constant albeit the indicator value is significantly different from the indicator value of the consumed activities. There is no step 6 combining results from different activity types as the places of employment values are processed separately from the other activity results.

A limitation of the methodology is the outputs from the consumed and supplied activities cannot be combined because they use a different basis for calculating their respective metrics. Further work is required to make the supplied activities (employment) compatible with the consumed activities metric. In particular it would be worthwhile investigating the LUPTAI (Land Use and Public Transport Accessibility

Index) approach (Pitot et al 2006) which applies a factor to the number of jobs, acknowledging only a small proportion of census employment jobs are actually 'available' to a household.

17.3 Applications

The accessibility score methodology outlined in this report provides a way to calculate the accessibility of a site at a given time. It is a measure of the distribution of land use activities and their relationship to the available transportation networks.

17.3.1 Land use and transport network changes

It is possible to model changes to land use provision, network changes or a scenario incorporating a combination of these changes. The potential impacts on accessibility can then be considered by applying the accessibility calculation methodology to these modelled scenarios. This has been illustrated for both land use and network changes using Christchurch city as a case study (refer to section 16.2).

17.3.2 Incorporating demographics

17.3.2.1 Aging population

By adjusting the population weightings based on forecast changes in the population, the effects on accessibility of doing nothing in terms of land use and network changes while the population ages can be examined. Similarly changes in land use and transportation networks proposed today could be analysed for their immediate and projected effect on accessibility into the future.

17.3.2.2 Population weighted comparison of scenarios

When performing the accessibility calculation methodology at mesh block level, it is possible to incorporate demographics from the census data to better interpret the accessibility results and define 'need'. A refinement of this process is to calculate accessibility at a finer level such as at a household level, rather than at a meshblock centroid level, and aggregate the finer results within each meshblock and then compare census data. This method retains 'outlier' results that can be hidden if only dealing with meshblock centroids. A trial technique to identify households requiring transport 'need' has recently been piloted by Abley Transportation Consultants for Hamilton city.

Allowing for the incorporation of 'need' allows the accessibility scores to be weighted by the meshblock population so that proposals from different sites could be compared to see where the greatest net increase in accessibility would be realised. This measure would be similar to the 'network accessibility balance' measure proposed by Espada and Luk (2009).

17.3.2.3 Disadvantaged populations

Using the results for the aggregated accessibility score by mode of transportation to each activity type and combining this with census information on the size of disadvantaged population, it is possible to combine these results using a weighting matrix particular to this population group, eg wheelchair users[12], to provide an accessibility measure for this group. This result could then be compared to the result for the general population to provide a measure of the degree of inequality in accessibility for this particular user group.

[12] Note the example of wheelchair users would also require the development of a series of special network models which only included wheelchair accessible walking paths and accessible public transport (eg low floor buses) etc.

A similar study could be carried out to compare meshblocks within a city by adjusting mode weightings on a meshblock by meshblock basis using data from the latest census to determine mode importance, for example the percentage of households with access to a car.

18 Conclusions

This report outlines the development of a methodology to calculate neighbourhood accessibility in New Zealand by considering land use activity and transport mode opportunities for different demographic groups.

At the commencement of this report the question was posed, 'What is access and mobility?' This report has demonstrated that accessibility is more than simply achieving access because access by itself doesn't describe the quality of choice or ease of being able to reach a destination. Additionally, although mobility is a component of accessibility, simply improving mobility may not actually achieve improved accessibility. Accessibility then needs to be considered as its own area of study. Consequently traditional transport modelling tools are not appropriate means to measure accessibility and hence the development of the accessibility analysis methodology presented in this report.

The methodology included in this report includes a series of negative exponential equations developed for the four transportation modes of walking, cycling, public transport and private vehicle through an analysis of the NZHTS. The need to refine these values based on journey purpose has been identified but a larger sample size is required before these can be further progressed.

A fundamental difference between services one consumes which provide homogenous levels of service and a heterogeneous activity, ie places of employment, was identified. A harmonic series was selected to model the saturation of opportunity of consumed activities and the overall accessibility to supplied activities and places of employment within a city were summed together.

The accessibility methodology was tested in a case study for Christchurch city. This showed the spatial scalability of the methodology, as it can be run at both meshblock and individual parcel level without modification. The ability of the methodology to identify the impact on accessibility of both land use and transportation network changes was demonstrated by modelling the impact of a new hospital in Halswell, and a scenario where a bridge was located across the mouth of the Avon – Heathcote estuary.

Overall the authors consider the methodology developed and presented in this report is a step-wise improvement for the consideration of integrating land use and transport rather than only considering traditional three or four step mobility modelling. The more detailed and transparent treatment of a critical variable determining people's attitudes and behaviour – accessibility – means that capabilities, opportunities and mobility can be considered explicitly, rather than incorporated in travel demand assumptions as is common in the four-stage models.

During the development of the accessibility calculation methodology outlined in this report, a number of potential areas for refinement and further research were identified. These are discussed in the following chapter.

19 Further research and recommendations

19.1 Further research

There are many refinements that can be made to the methodology for calculating the various accessibility scores. This section outlines some possible refinements for further work. In the UK there is recognition that further research is needed to develop scores that can be used in policy but this research showed that useful scores can be calculated to apply in practice. In the short term the more robust accessibility indicators will continue to be the most transparent travel time measures by trip purpose and traveller group. However further work on developing composite accessibility scores could enhance the accessibility planning process.

19.1.1 Acceptable comprehensive accessibility scores

There are occasions when comprehensive accessibility scores can be usefully combined to show comparisons of accessibility between locations based on demographics. However, for a comprehensive accessibility score or threshold indicator to be incorporated into government policy, more work is needed to understand the performance of accessibility and the sensitivity of the indicator to change. This is because comprehensive accessibility scores, similar to other aggregate indicators, can hide more than they reveal.

Threshold indicators on the other hand may be more appropriate for providing a focus for activity as a highly segmented people-focused approach. Acceptability of an accessibility indicator could vary depending on location, for example rural compared with urban areas, and other factors. Such approaches have been used in The Netherlands, eg the 1989 ABC planning policy (Ebels 1995) although in that example, the policy proved difficult to maintain and has fallen into disuse.

Even so, the setting of accessibility targets could be done in a similar way to how larger communities define acceptable levels of service, such as through national standard setting, or medium to smaller communities set through district or long-term council community plans.

19.1.2 Deterrence functions

If the method of determining deterrence parameters was repeated using an even larger survey size, then statistically significant results by trip purpose may be determined. This would allow modelling of separate parameters based on each land use (journey purpose) and transport mode, leading to an improvement in the quality of the derived accessibility analysis.

An increased survey size could be achieved by either immediately expanding the sample size of the NZHTS, or waiting until the addition of successive years of data has sufficiently increased the size of the NZHTS dataset.

Therefore, the following recommendations are made:

- The deterrence parameters that have been developed for the transportation mode types for various OD types should be revised when updated travel survey data becomes available.
- The analysis of the deterrence parameters should be extended to include other modes of transport such as taxi and train once the sample size for these modes reaches an acceptable size.

Even so, the measurement of the deterrence parameters using the NZHTS assumes ‘measured’ behaviour reflects ‘desired’ behaviour. Strictly speaking this is incorrect because measured behaviour already includes the spatial distribution of the transport network and land use. Consequently measured behaviour is already influenced by 'need', 'accessibility' and a number of other factors specific to the individual undertaking the specific journey.

Although, in the interest of pragmatism, deterrence parameters derived without reference to the NZHTS would be more ideal, the current approach is considered appropriate. This is an area of future study although in the interim, it is hoped that further analysis and understanding of the NZHTS to account for the difference between measured behaviour and desired behaviour will assist to determine and refine the appropriate deterrence parameter values. Additionally it might be that research regarding travel adaptive capacity assessment can be used to supplement the NZHTS data (Krumdieck et al 2012).

Regardless, if the NZHTS is used in its entirety or supplemented with 'desired' behaviour, the data should be tested using logistic decay functions that are expected to produce better mathematical fitting models than a negative exponential function (λ).

19.1.3 Weightings

For the purposes of this research, the weighting matrices used to assign the importance of each transportation mode and land use activity by age group was based on 'best assumed' assumptions. The weightings for land use activities considered not relevant to a particular age group, ie not able to be used by the age group, were given a weighting of zero.

If the comprehensive accessibility score proved useful, then research to identify both the potential mode split (behaviour) and availability of each of the transportation modes (ability) by age, would improve the weighting matrices used in the accessibility calculations. This would result in a better and more robust composite indicator.

19.1.4 Economic costs

By incorporating the economic costs, real and perceived, of travel into the network models, it would be possible to compare modes based on generalised cost. This would also enable the investigation of socio-economic status on accessibility, and vice versa. This is consistent with the development of behavioural economics theory and approaches to address the weaknesses of current normative economics – not least the distributive and social aspects where accessibility planning adds particular value.

Developing a network cost model would need to account for the cost of a person's time, vehicle operating costs, interchange costs, safety and amenity costs and the economic savings due to the health benefits of walking and cycling as well as many other factors.

Incorporation of economic costs into the model would make it possible to calculate the economic benefits of various scenarios. This would then enable the formulation of benefit–cost ratios so intervention scenarios could be compared.

19.1.5 Additional land uses

Consideration should be given to the identification of other significant land use activities that would be of relevance when calculating the comprehensive accessibility score. One example is open space, for example parks and squares, that provide opportunities for recreation and exercise which in turn can lead to improvements in health and quality of life of a community. The accessibility score methodology easily accommodates additional land use activities. It would be worthwhile for further research to be undertaken to establish the relative significance of each of the land uses by age group.

19.1.6 Additional transportation modes

The development of the accessibility modelling methodology included four transportation modes to calculate accessibility scores. To improve the accessibility analysis, additional transportation modes could be considered such as demand responsive transport including taxis and on-demand bus services.

19.1.7 Car parking

Calculation of private vehicle trips assumes the vehicle travels directly between the origin, ie home, and the final destination, ie the land use activity. In reality, a parking space must be found near to the destination, and then a walking leg undertaken to reach the destination. The walking distance between the parking space and the destination, land use activity, will depend on the particular activity. For example, patient parking is usually provided within close proximity to doctors' surgeries and therefore the resulting walking leg would be short, whereas parking may not be available directly at all workplaces, and therefore a longer walking leg would be required. Incorporation of this aspect into the modelling accessibility would further refine the results. A possible methodology has been included in an accessibility pilot study undertaken in the Heretaunga area for the NZTA on behalf of Hawke's Bay Regional Council and in Hamilton city for the Hamilton City Council.

19.1.8 Additional determinants of opportunity

The methodology for calculating comprehensive accessibility scores outlined in this report includes weighting of the scores based on the age breakdown of the population, as age is considered an important determinant for the relative opportunity of an activity. Many other demographic variables are also determinants of opportunity including:

- car ownership and availability
- household income
- mobility and/or sight impairment.

The inclusion of the above factors would further refine the accessibility scores. Alternatively a methodology similar, but improved, to determine 'need' such as that proposed by Currie and Senbergs (2007) would be useful.

19.1.9 Opportunity saturation

Further work should be undertaken to improve understanding of the rate at which the value of more competing opportunities diminishes for different activity types, eg having opportunity to the second or third convenience store may provide very limited additional benefit as might the tenth and eleventh primary schools. Quantifying these saturation levels is possible using a spatial analysis of the NZHTS.

19.1.10 Mode speeds

A generic mode speed has been assumed in the current methodology for each transportation mode. However, walking and cycling speeds vary considerably due to age group and other factors. Therefore, assigning different walking and cycling speeds for different age groups would provide better quality results. This could then be used to test the accessibility of sight or mobility impaired people or school children to key facilities. Again this is a fertile area for further research.

19.1.11 Distribution of travel times

The present methodology assumes that the distribution of travel times generated by those participating in the NZHTS is representative of the entire population. It is probable that people who used active modes in particular to access activities in the NZHTS, ie walking or cycling, may not be representative of the wider population. Further research is recommended to identify how far people are prepared to travel to activities by various modes and it may be the work of Krumdieck et al 2012) provides this opportunity.

19.1.12 Time factors

The modelling methodology is currently based on an interpeak period. In reality, people need to access different activities at different times. For example, places of employment and schools are generally accessed during the am peak period, whereas access to doctor's surgeries is more likely to be during an interpeak period. Therefore, further work should be undertaken to establish the most appropriate time period for each assessment.

19.1.13 Data input standards

Data exchange and inputs for transportation mode networks must be standardised to ensure these networks are comparable between locations in New Zealand. If different methodologies are used to develop these networks, then the resulting accessibility scores will not be comparable.

19.1.14 Methodology validation

The accessibility methodology has been calibrated using behavioural characteristics such as inputs from the NZHTS. It is a typical process for model outputs to be validated against an independent set of data. Validation of the accessibility outputs resulting from the research methodology has not been undertaken although there was always an expectation the output of the methodology would be confirmed by community perception surveys. The methodology for undertaking this work, including the source for the independent set of data, and the basis for the validation eg time, cost or a combination of both, should be developed. It may be that the accessibility results could be tested against say, journey-to-work mode split data although the results would have to be used cautiously because mode split data reflects what people 'would' do, and not what people 'could' do.

19.1.15 Presentation

Develop a common set of presentation tools such as representative colours, raster images and/or similar formats if appropriate so accessibility assessment presentations are delivered in a common design to facilitate understanding. The accessibility analysis recently completed for Hamilton City Council would help in this regard.

19.1.16 Resource vulnerability score

Measuring accessibility provides the ability to extend the methodology to other areas of study, eg assessing the vulnerability to issues such as resource dependency. Measuring the dependence on 'oil' for the private motor vehicle for a nation, region or city/town would be a fairly simple extension of the accessibility score methodology. This would enable the quantification of a particular area's potential minimum energy use to be determined (reflecting what people 'could' use) and then compared against actual energy use (what people 'would' use). The indicator may result in a 'resource vulnerability footprint' that would enable comparison between areas and help direct policy. A methodology similar to that proposed by Abley et al (2011) could be appropriate.

19.1.17 Quality of route choice

The New Zealand accessibility methodology is currently based on shortest time-based route choice. However, it is known that the quality of a route using a particular mode influences whether a person chooses to use that route. For example, a busy arterial road with many heavy vehicles and no bicycle facility is less desirable for cyclists than a quiet back street. Higher levels of route quality are expected to influence accessibility.

The effect of quality is particularly pertinent for cyclists and pedestrians and to a lesser extent private vehicle travel.

With regard to cycle route quality, a methodology is the Abley Cycle Route-Choice Metric (ACRM) proposed by Rendall et al (2012). Regarding walking quality, a possible methodology is that proposed by Abley and Turner (2011) although further work would be required to apply the level of service outputs to route weightings.

19.1.18 A single comprehensive accessibility score

The opportunity to fully develop an indicator that accounts for supplied and consumed activities would ease the understanding of accessibility. Further research into the area of combining indicators and developing appropriate indicators for the New Zealand context would be worthwhile. Even if it did not prove possible to agree on a single score the debate about what score to use would highlight and promote many important transport planning issues, including educating transport planning professionals on the usefulness of measuring and quantifying accessibility.

19.2 Recommendations

This research provides a methodology that documents how to develop an accessibility assessment tool that has geospatial outputs. The sector may now wish to determine how it might utilise this tool, including how it would be best to roll it out to other potential users and whether to undertake further research to assist the tool to develop.

In terms of **management and delivery** of the accessibility methodology, accessibility tool and accessibility planning techniques, Abley Transportation Consultants recommends the sector considers the following:

1 Nurture the development and maturity of accessibility modelling with the anticipation of forming an industry management group consisting of relevant NZTA staff, other agency and/or government staff (who are interested in accessibility mapping outcomes) and external technical expertise. This two-part approach would assist in cementing the immediate ‘intellectual high ground’ and after suitable maturity and proven usefulness, the latter part would cement the ‘technical high ground’ with the wider transportation planning industry.

2 Instigate a review to consider how the accessibility modelling tool might be delivered to the wider transportation planning profession. This would include the advantages and disadvantages of the centrally controlled approach, eg the MoT’s Crash Analysis System (CAS) versus a decentralised yet still governed role, eg road assessment and maintenance management (RAMM), versus a fragmented approach, eg existing transportation modelling. It is the opinion of Abley Transportation Consultants that a decentralised yet still governed approach provides the best balance for central government investment, quality of assessment and providing for innovation.

3 Increase the role and relevance of the New Zealand Geospatial Office (NZGO) for transportation (and indirectly accessibility modelling) by becoming a partner organisation of the Geospatial Executives

Group (already actioned by NZTA). This is expected to increase the ease of data sharing and data enhancement across government. The addition of a representative from the NZGO onto the industry management group would be a natural extension of the increasing relevance of the NZGO.

4 Undertake a number of accessibility assessments that would test various approaches and develop linkages with other assessment techniques and processes such as the NZTA's *Economic evaluation manual* (NZTA 2010) neighbourhood accessibility plans, integrated transportation assessments (Abley et al 2010), network plan development, regional land transport plans project prioritisation, and to inform other integrated planning projects. These applications would refine the methodology, provide examples for how the methodology is best used in practice and ultimately inform the wider transportation planning industry of the usefulness of accessibility planning.

5 Task the industry management group (when set up) to consider issues such as management of the accessibility methodology and promotion of the field of accessibility planning including education at academia, and local and regional government as well as private interests and the wider transportation profession. Suitable linkages to the profession could be through supporting organisations such as the New Zealand Planning Institute, Institution of Professional Engineers New Zealand, Local Government New Zealand and the Ministry for Environment.

In terms of **development and refinement** of the accessibility methodology and accessibility planning techniques, Abley Transportation Consultants recommends the following:

1 Commission further work immediately to develop data input standards regarding metadata and network coding to assist the transportation community to conform to a best practice code. This will lessen the amount of rework regarding network creation, editing, updating and aid knowledge growth and transfer within the profession. A standardised New Zealand public transport coding system that requires or incentivises operators to supply public transport data when registering routes as per the Public Transport Management Act 2008 would be particularly useful.

2 Develop indicators for how accessibility measurements can be interpreted including a methodology that explains how threshold and continuous indicators are best used in practice, their calculation methodology and the reasons why certain values are appropriate. Composite indicators which are a combination of indicators, such as the comprehensive accessibility score that has been developed as part of this research, can be developed later.

3 Create a national accessibility transportation model to benchmark and potentially track trends in accessibility for different local and regional authorities. This would help inform the setting of specified levels of accessibility 'success' by mode and activity and help inform the development of accessibility indicators. The outputs from the work would also assist to inform the Ministry of Transport's Transport Monitoring Indicator Framework.

4 Support the further research identified in Part 3 of this report, identifying high-priority and complementary research first, and commission all or parts of this research as funds or support in kind allows. This would lessen the risk of the accessibility methodology fragmenting into different approaches.

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Appendix A: Trial of Accession

A1 Background

This section describes a trial of the Accession software package in New Zealand. The main focus was to evaluate the suitability of using Accession in New Zealand given the topical interest in this product at the time. This assessment was undertaken in 2008.

The trial provides a brief overview of Accession's capabilities but it does not attempt to describe all the settings and model parameters available within the software or the software usability.

The Accession software was originally developed by MVA, a UK transportation consultancy, to automate accessibility calculations for local authorities. Accession was one of the software packages developed with funding from the UK Department for Transport and is a commercial product now distributed by Citilabs.

A2 Calculation flowcharts

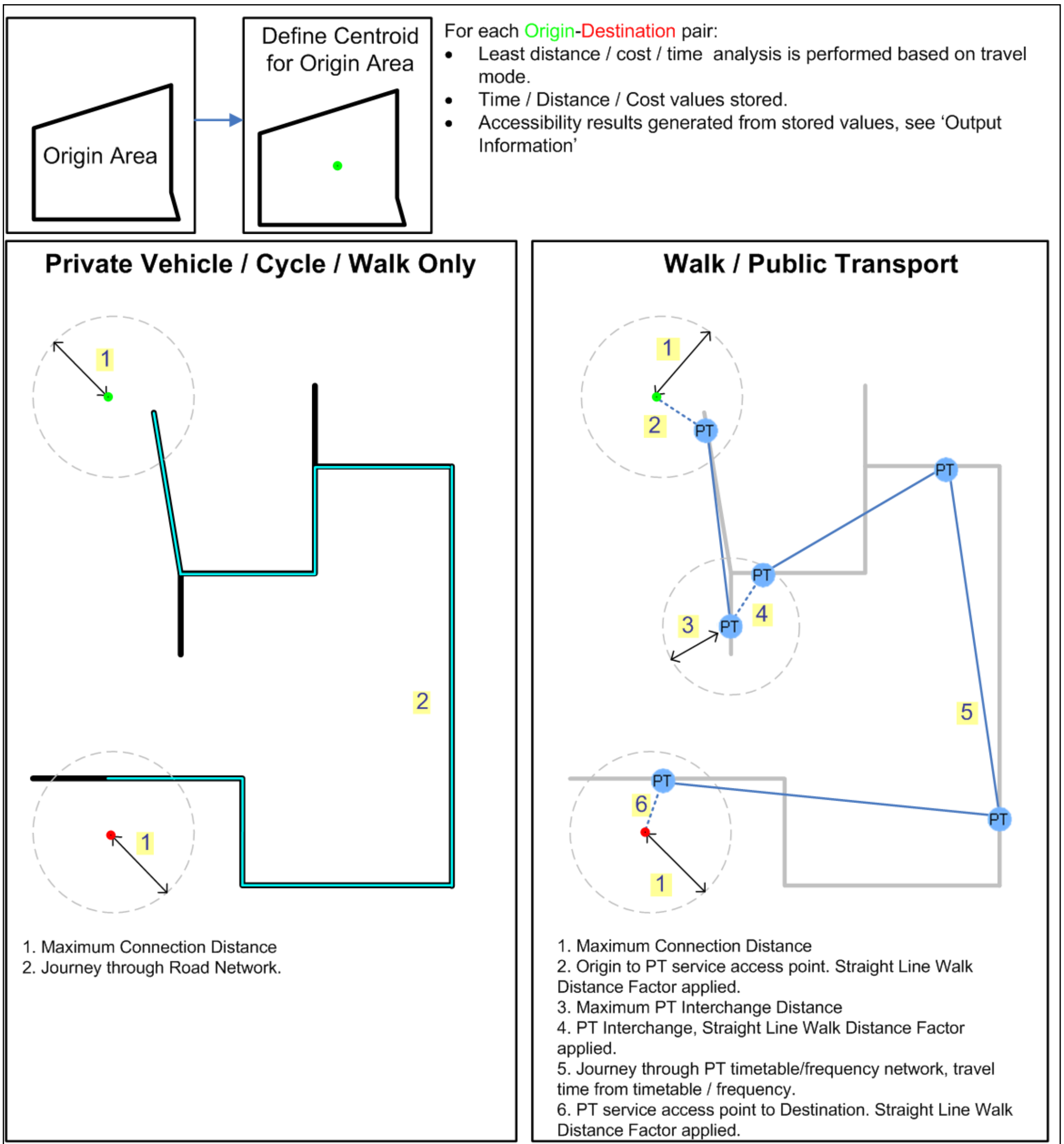
This section describes accessibility calculations based on the Accession modelling software using two diagrammatic flowcharts. The flowcharts refer to network calculations and output information.

The network calculations shown in figure A.1 illustrate how travel through the network is modelled. It also includes a list of variables and common UK values for these variables.

The output information shown in figure A.2 illustrates the various outputs, shows where this information is calculated from and provides subsequent calculations.

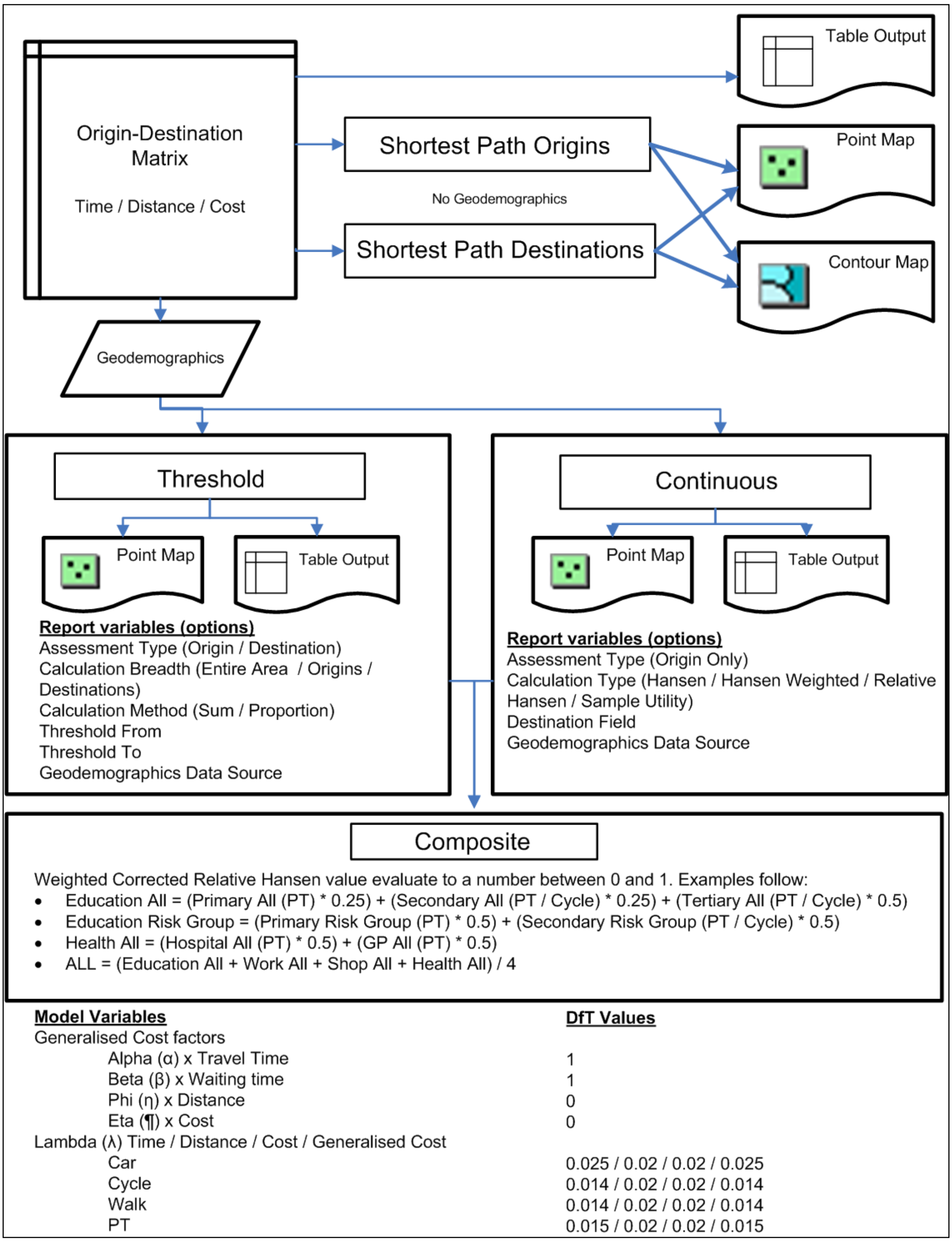
Several of the parameters are different from the values used by DfT. The calculation approach varies depending on the selected methodology. The design of an approach for New Zealand should reflect the policy and analysis needs for measuring accessibility.

Figure A.1 Accessibility assessments network calculations



Model Inputs (Example)	**Model Variables**	**Common UK Values**
Origins (Meshblocks)	Vehicle Speed	Conditional on Road Type (Hierarchy)
Destinations (Dentists)	Vehicle Cost	0.1 £/km
Road Network	Average Walking Speed	4.8km/h (1.33m/s)
Road Hierarchy	Average Cycling Speed	16 km/h (4.44m/s)
PT Stops	Straight Line Walk Distance factor	1.2
PT Timetable / Frequencies	Maximum Connection Distance	2000m
	Maximum PT Interchange Distance	500m
	Time Period	Morning Peak / Interpeak / Afternoon Peak / Evening
	Sampling Interval	10 Min
	Maximum Journey Time	120 Min
	Calculation Type	Time / Cost / Distance

Figure A.2 Accessibility assessments output information



The process for undertaking accessibility calculations differs if the indicator is origin or destination based. The destination-based calculation process is described in table A.1.

Table A.1 Steps in destination indicator calculation

Step	Task	Method	Output
1	Identify nearest service of defined category for each COA	Routing algorithm identifies shortest route	Two column matrix showing COA and travel time to nearest service
2.	Calculate COA level population catchment for target group and "at risk" population by threshold.	Sum the populations of each COA within a defined threshold (e.g. 15 min, 30 min)	Absolute form of threshold indicator (e.g. 3500 0 car households within 30 mins, 1750 within 15 mins)
3	Calculate COA level continuous population catchment for target group and "at risk" population.	Weight the population of each COA by the exponential[2] of the travel time to nearest service.	Absolute form of continuous indicator (e.g. equivalent 2700 0 car households)
4.	Aggregation to LSOA, local authority and transport authority level	Combine COA indicators to LSOA level using the target population to weight the separate indicators.	Absolute form of indicators at each geographical level presented separately for PT/walk, PT/DRT/walk, and cycle
5.	Combined measures by mode	Weight the values of the indicators for each separate mode by the percentage modal split from the national travel survey (1999 to 2005 average) and divide the composite value by the total percentage modal share for the combined modes.	Absolute form of each of the indicators in Steps 3 to 6.

COA – census output area - is a three-tier hierarchy consisting of seven (super-groups), 21 (groups) and 52 (sub-groups)

LSOA – lower layer super output area - there are 34,378 LSOAs in England and Wales

[2]In the exponential function the shape of the curve depends on the lambda parameter which is estimated based on observed sensitivity to trip time

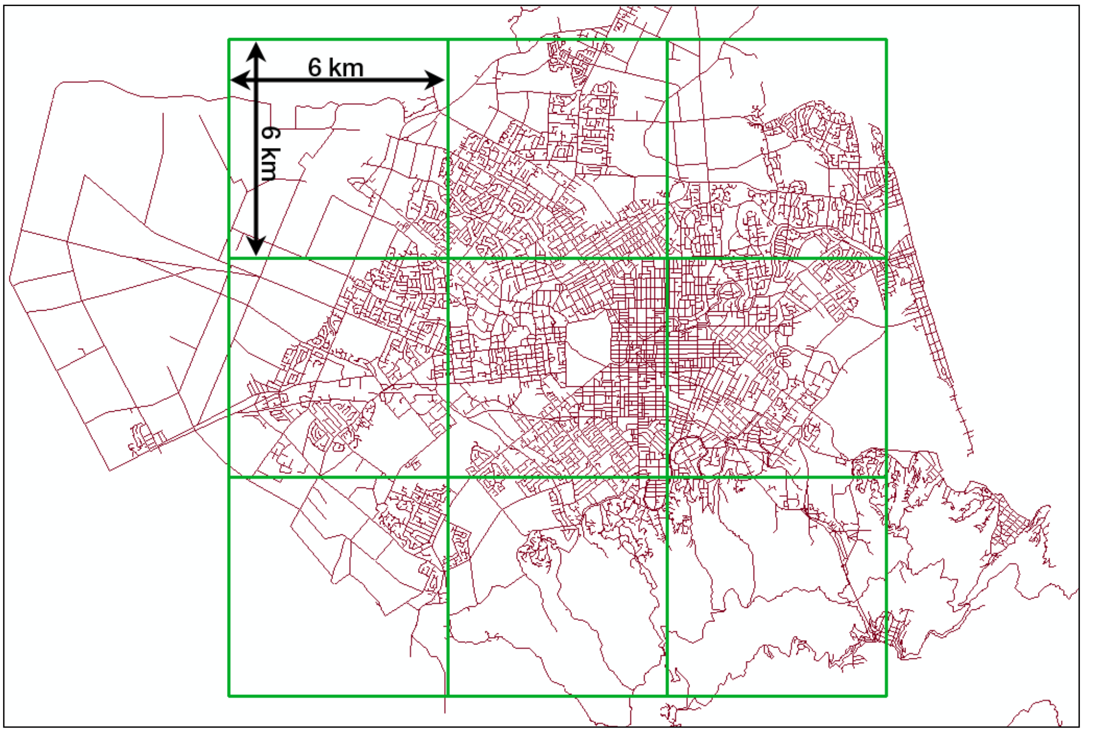
Source: DfT 2008, table 4.1

A3 Basic trial

For the purposes of this research report, a simple accessibility assessment was carried out using version 1.6.0.0 of the Accession software (2008). The current version of the software is version 1.6.2 (November 2012).

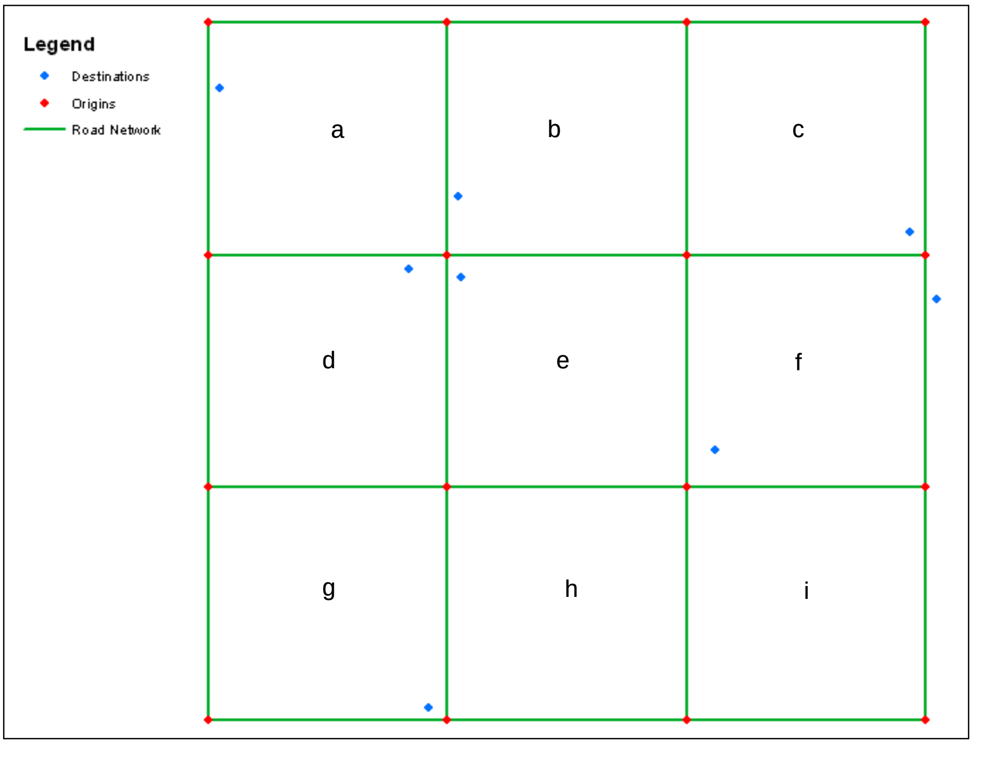
A basic road network was created using a 3x3 matrix roughly the same size as Christchurch city. This was done so the testing methodology could be compared to the calculations undertaken in section 12.4 where basic accessibility calculations are undertaken on a citywide basis in Christchurch. The 3x3 matrix overlaid on the Christchurch city road centreline GIS layer is shown in figure A.3.

Figure A.3 Basic 3(6km) x 3(6km) matrix (32.4Ha)



The matrix was then populated with sample origins at each of the intersecting nodes and sample destinations randomly clustered within each of the matrix cells and around each origin (shown in figure A.4). All testing was performed on this very simplistic network. Each of the matrix cells is titled with a letter for later reference.

Figure A.4 Network connectivity



A3.1 Configuration and calculation

The option exists to undertake accessibility calculations using a number of modes including:

- public transport and by inference walking
- public transport and by inference walking, private motor vehicle, cycle and walking; each as separate modes
- road only.

In this example 'road only' is the only option available because the 3x3 network is a road-only network and excludes public transport, walking and cycling. A road-only network was created because this is the most simplistic assessment possible. Inputting public transport information would require importing data via the standard UK public transport data interchange formats (DfT 2011b).

The option exists to adjust a number of model variables including:

- speed when travelling on the network by different modes
- 'crow flies' straight line network distance factor depending on network connectivity
- the maximum connection distance between OD centroids and the physical network
- the length into which a link can be subdivided for refined analysis.

For this test the following settings were selected:

- walking speed 4.8km/h
- car speed 48.27km/h
- cycle speed 16km/h
- straight line to detour distance factor of 1.2
- maximum connection distance from the OD centroid to the road network of 1km
- increased road accuracy was selected which allows Accession to break up long network lengths into smaller links so OD centroids can connect to these intermediate points.

The length the network link can be subdivided into is set by the user and should be related to the maximum connection distance from an OD centroid.

Accessibility is assessed in a number of ways based on different settings for the following:

- inbound or outbound travel
- minimum time, distance or cost
- catchment.

For this example the following settings were selected:

- outbound travel – the trip begins at the origin and ends at the destination
- minimum distance
- no catchment analysis – all OD trips will be calculated in full, regardless of the time taken to complete the trip. If this box is selected, the routing calculator will abort calculation after the specified threshold is reached and assign an accessibility value of 0. This variable is used to limit overall calculation time.

Once all the input data is specified, Accession estimates the complexity of the resulting calculations**.** This is an important step because accessibility calculations, if undertaken on a large area using detailed timetable and multiple OD data points, can quickly become excessively time intensive.

For this simplistic example the calculations are within the parameters of a 'very small calculation'. This reflects the limited size of the network and the 128-cell OD matrix and the performance of the hardware. The time taken to undertake this calculation was essentially instantaneous.

There are a number of outputs that can be generated by the software including:

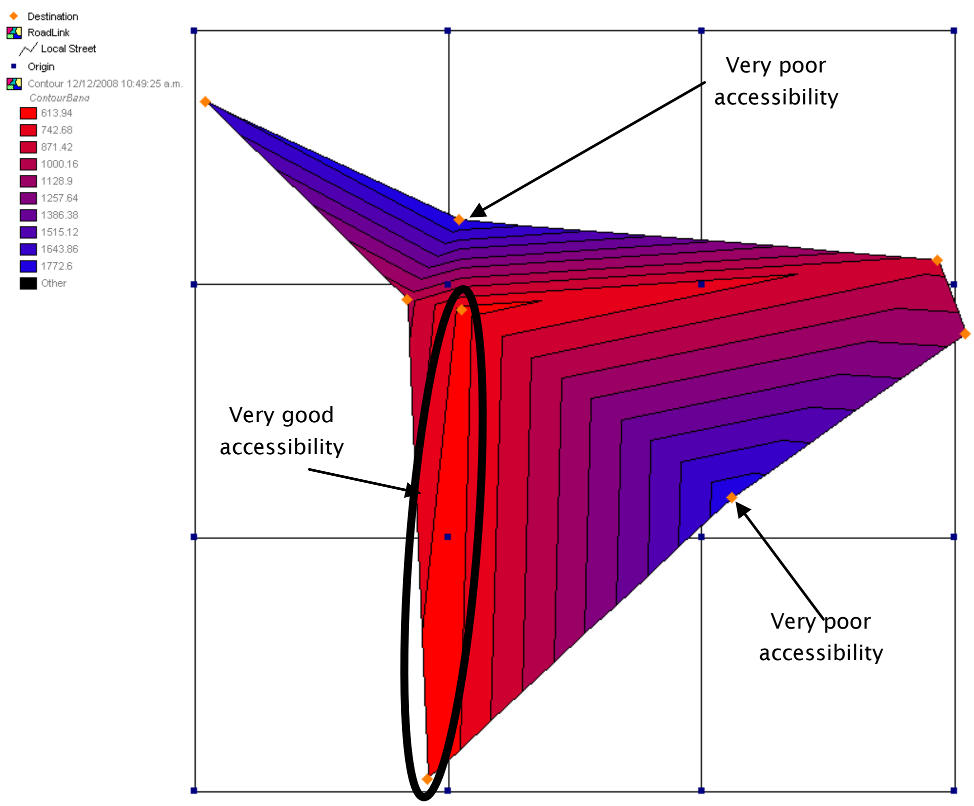
- the type including main table, shortest path origin or shortest path destination
- output types including a report, point information or contour information
- continuous and threshold reports can also be selected.

For this example a contour output was selected. As a contour output was selected, the particular graduations and colour of the contoured output could also be chosen.

A3.2 Results and testing

The output contour information is based on a generalised distance-based cost. It is important to remember the output describes the accessibility of the destination. The shape of the contour map is a polygon that connects the destination locations. The output from the preceding inputs is shown in figure A.5.

Figure A.5 Graphical output (no modification)



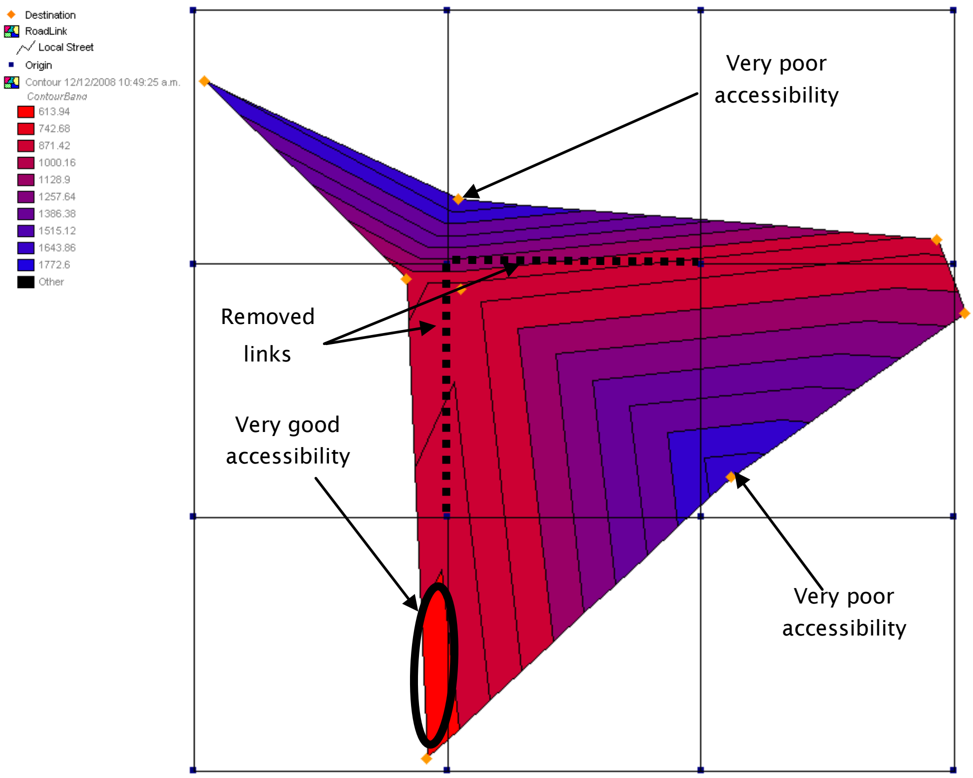
It is interesting to note from the accessibility analysis that destination locations closer to the network and origins have a higher accessibility. This is unsurprising given this is the basis of the accessibility calculation. Where origins and destinations are close together, the accessibility of the destination will be high. What is interesting though is a contour plot, which requires three points to interpolate accessibility, shows large areas that could appear to have no (rather than low) accessibility. This is not correct. As the plot is destination based there are no destinations within these white areas so the contours are not able to be inferred for these locations.

It is also interesting to note there are at least two points close to the network and close to an origin in cells a, b and f, which appear to have very poor accessibility. This is an abnormality because theoretically, these points should have connected to the network. It is unknown why these points did not 'connect' to the network.

Trialling variations of the standard analysis and removing two of the central links bordering cells b and e, and d and e, results in a changed spatial pattern of accessibility as shown in figure A.6.

The result is accessibility decreases around the points in cell e where one of the destinations can now no longer connect to the network within the minimum 1km distance specified. This means the destination at the bottom of cell g continues to have high accessibility but the area of very good accessibility has decreased.

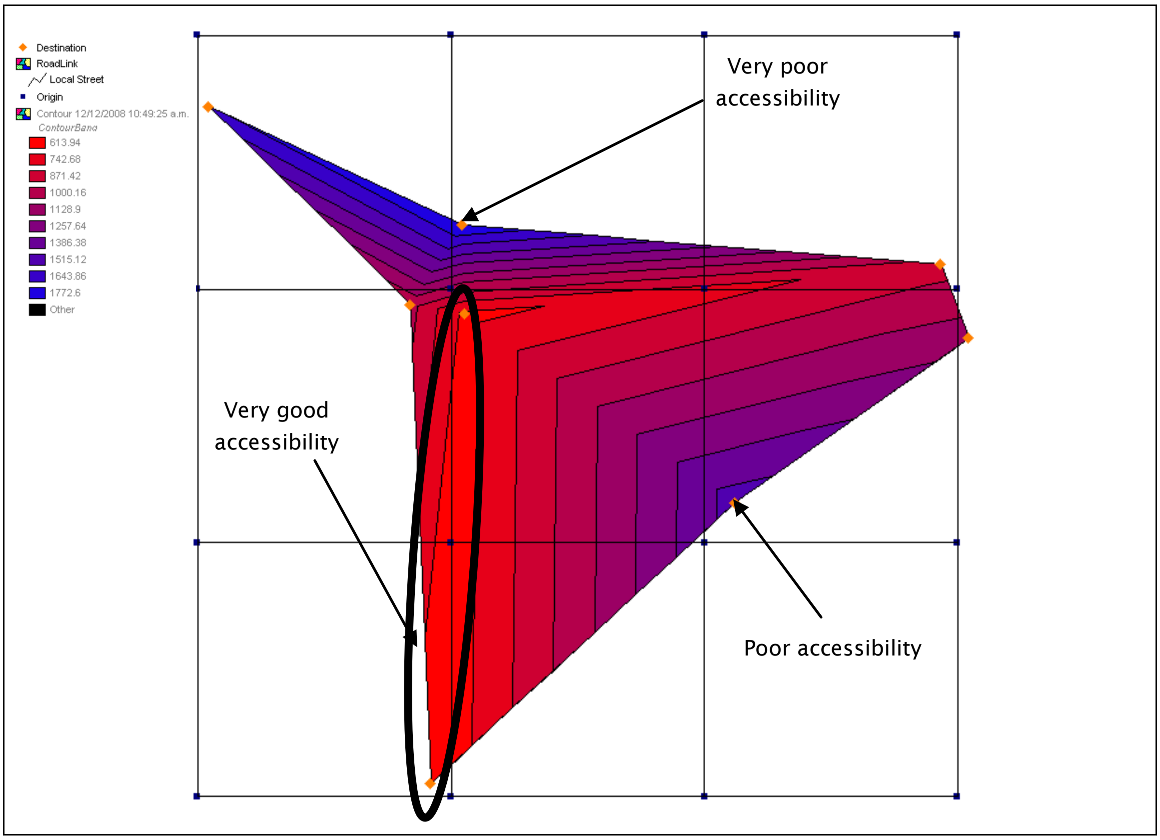
Figure A.6 Graphical output (less two links)



Increasing the minimum 1km connection distance to 2km results in the pattern of accessibility changing as shown in figure A.7.

The result is accessibility improves over the whole area as there are now more destinations able to connect to the network. Again, the only abnormality to this is the three points identified earlier in cells a, b and f that are still unable to connect to the network. Even so, accessibility can be seen to have increased, and this difference can be seen when comparing figure A.7 with figure A.6.

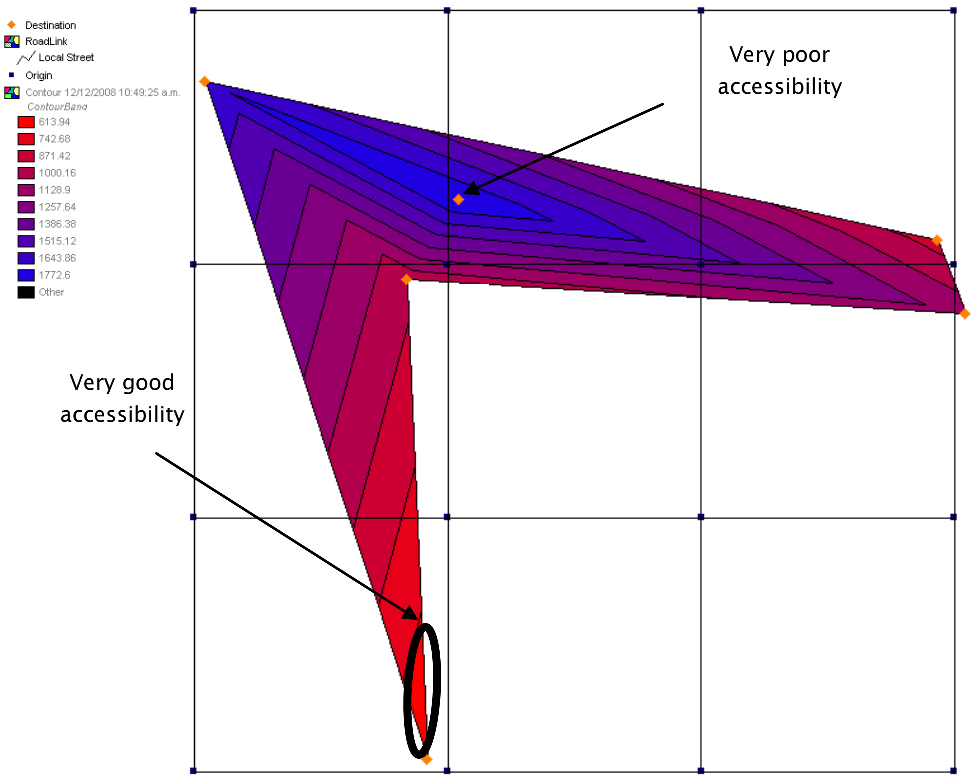
Figure A.7 Graphical output (max 2km connection)



Removing two of the destinations, one in cell e and the other in cell f results in changed accessibility as shown in figure A.8.

The analysis does not differ greatly from the original analysis other than the polygon shape has changed to reflect the removed destinations.

Figure A.8 Graphical output (two destinations removed)



A3.3 Discussion

This simple analysis using Accession demonstrates the visual outputs of the software. Disappointingly, the calculated accessibility value is not outputted in the corresponding Excel table, rather the table outputs each OD calculation including time, distance and cost. There is no field in the table for the value that is output in the contour or point map.

It is important to note there are a multitude of output options from Accession and this section has only briefly presented some of the possible analyses.

A4 Christchurch case study

A4.1 Introduction

To further test the capabilities of Accession, particularly for the New Zealand context, a case study was set up using Christchurch as the subject area. The accessibility by private vehicle to general practitioners in Christchurch was used as an example to examine the capabilities of Accession.

A4.2 Configuration and calculation

The Christchurch road centreline network GIS layer was imported into Accession. Accession is 'hard wired' to classify roads using the UK Ordnance Survey road classification system, so Christchurch road hierarchy values had to be assigned to one of the Ordnance Survey road classes. The matrix used to transform the Christchurch road hierarchy classification to an appropriate Ordnance Survey class is shown in table A.2.

Table A.2 Accession road hierarchy classifications

Christchurch road hierarchy	Ordnance Survey class
Motorway	Motorway
Major arterial	A road
Minor arterial	B road
Collector	Minor roads
Local road	Local street
Private road	Private roads (public)

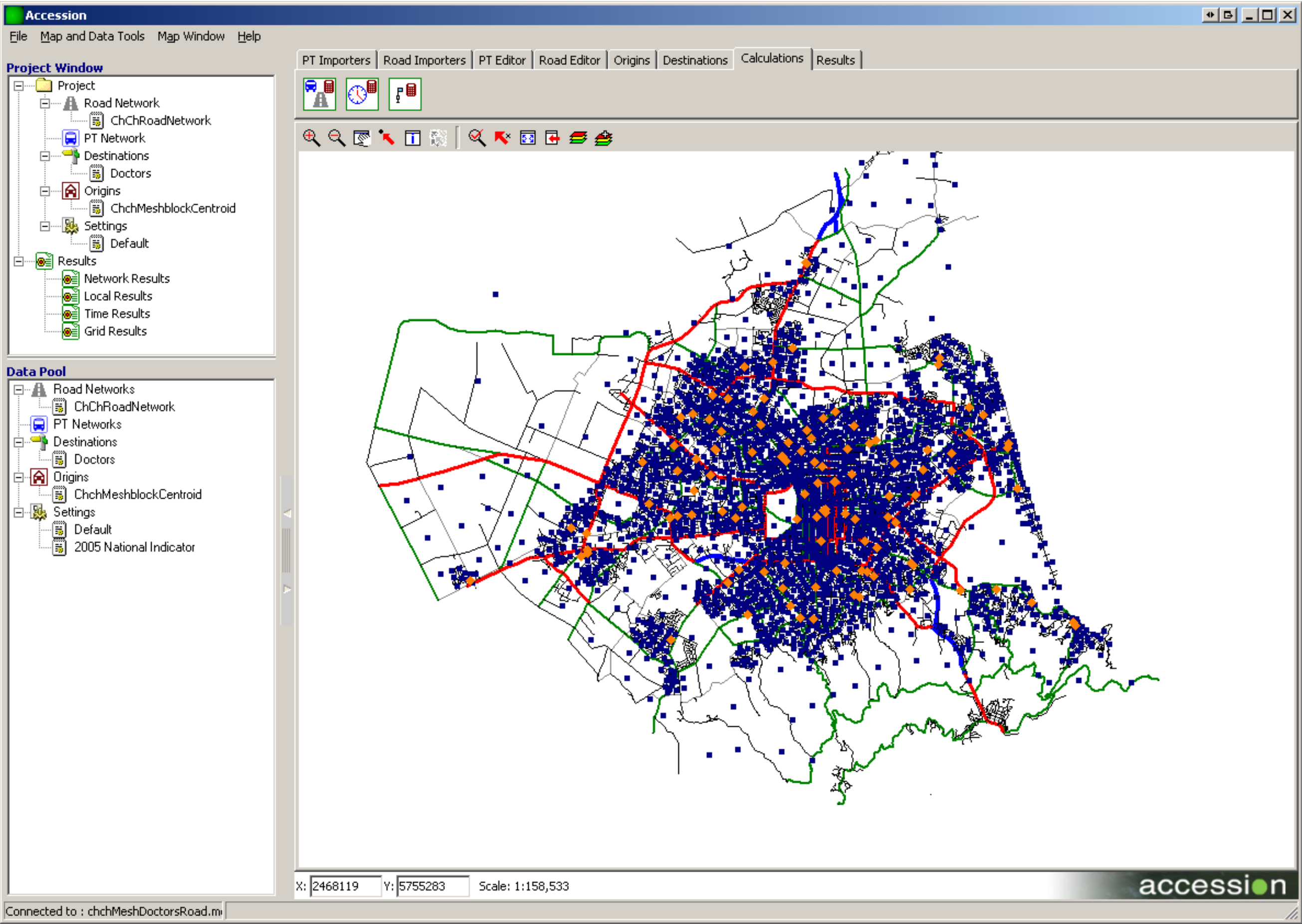
Road speeds were assigned to the road network. A road speed value is assigned to vehicle, cycle and walk modes. In the case of a mode type not being able to use a particular road link, for example cyclists and pedestrians not being permitted to use motorways; road speed values for these modes are assigned as 0, making the link non-traversable by that mode.

One-way street and turn restriction data was not included with the road centreline dataset as this required additional data capture. Manually coding each one-way link and turn restrictions was not considered beneficial at this stage of the project. A total of 9853 road links were imported into Accession to form the Christchurch road network.

For the purposes of demonstration and performance assessment of Accession, the accessibility of general practitioners from meshblock centroids through the road network was calculated.

The centroids of Christchurch city meshblocks were used as the origin dataset. Similarly, a point dataset of general practitioners in Christchurch was imported into Accession for use as destinations. Importing point data into Accession to represent origins and destinations is a simple process. A screenshot of Accession, showing the Christchurch road network, meshblock centroids (blue square) as origins, and general practitioners (orange diamond) as destinations is shown in figure A.9.

Figure A.9 Christchurch city GIS data loaded in Accession



The analysis was undertaken for trips taken across the road network in a private motor vehicle. As public transport data is not currently available in New Zealand in a suitable format for import into Accession the ‘road only' network was the only available option for this trial.

The default values currently used in the UK were selected for the analysis. Figure A.1 and section A3.1 outline the default values used by Accession.

The road node spacing option is a method Accession uses to break up road sections so connections between origins and destinations can be made at road nodes that connect two links. More frequent road nodes, and therefore smaller distances between nodes, provide better accuracy for connecting OD points to the road network. Conversely this option also increases processing times for modelling. A value of 1000m was selected to reduce the processing time of the model.

At this stage of the modelling dialogue, Accession asks the user to specify network speeds for walk, car and cycle. This is limiting because cars and the other transport modes move at different speeds depending on the specific location of congestion, road type and topography, although Accession does not differentiate been these variables. It is also confusing because network speeds are already set in Accession when the road network is imported as the user specifies network speed based on road type. The Accession help file fails to explain which of the two road speed values is used for the calculation of accessibility. Regardless, in this trial the two have been set to the same value.

Accessibility can be assessed in a number of ways. For the purposes of this trial, the calculation of accessibility was based on the shortest travel time between the origins and destinations.

Catchments are used in Accession to optimise the calculation time by stopping calculations once the accumulated value (time, distance or cost) exceeds the catchment unit maximum. Selecting a value of 30, means once trips from an origin to a destination exceed 30 minutes, the routing algorithm will be aborted and the accessibility value for the particular OD pair will be recorded as 0.

The next stage of the dialogue presents a screen to the user, summarising the calculation that is about to be undertaken and an estimation of the size of the calculation. The combination of 2710 meshblocks (origins) and 113 general practitioners (destinations) will generate 306,230 OD values and Accession estimates this as a 'large calculation'.

Despite this estimation the processing time to calculate the OD routes was only about 10 minutes. The computer that ran the calculations was a standard desktop computer with a 2.6GHz Core 2 Duo processor and 3.5GB of RAM. The results are stored in a database with a maximum size of 2GB. The size of the database generated by this test was 240MB.

The output from the calculations was a matrix including travel time, cost and distance. This matrix can be output to Microsoft Excel and assessed in more detail as required. This matrix result is the 'OD matrix' pictured in the output information flowchart in figure A.2. It was noted it took longer than 10 minutes to export this dataset to an Excel spreadsheet. Once the network results had been exported they were then available to be analysed for specific accessibility assessments.

A4.3 Results and testing

The results of the calculations are shown with varying degrees of interpolation in figures A.10, A.11 and A.12. Figure A.10 demonstrates an aggressive level of interpolation and hence provides the finest grained output. In contrast figure A.12 shows a more relaxed interpolation and consequently displays flattened contour lines.

Figure A.10 Christchurch meshblock accessibility to GPs, aggressive interpolation

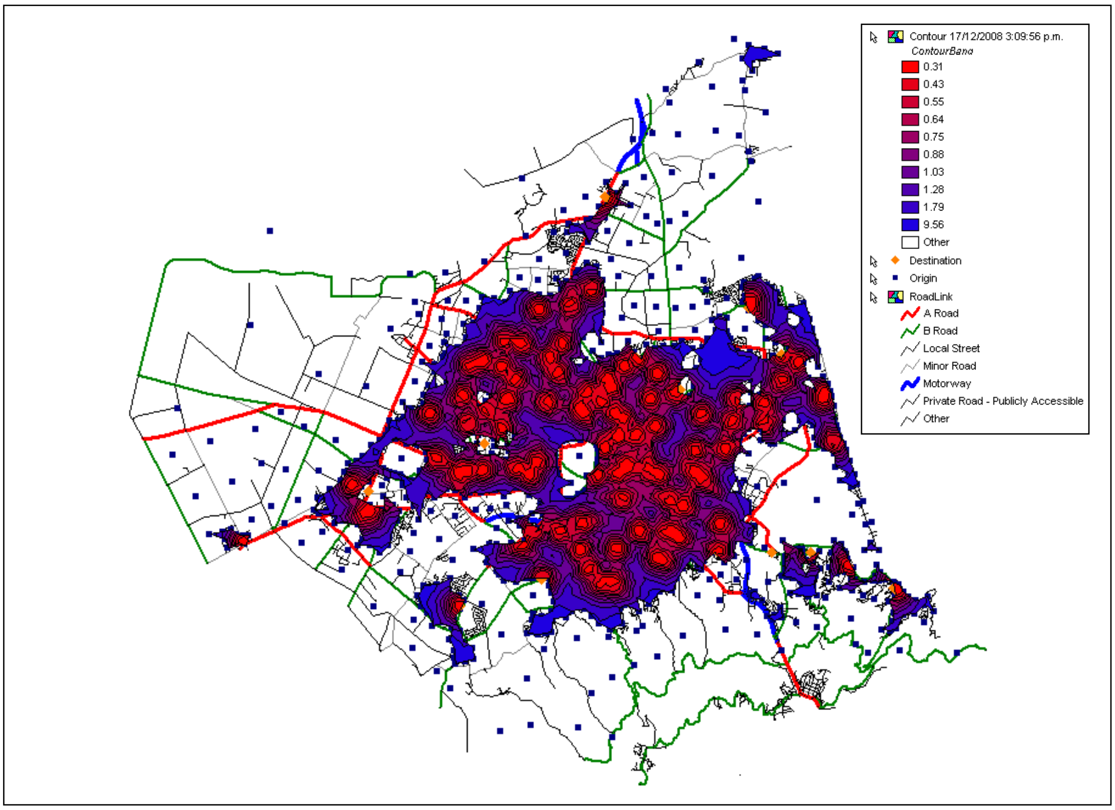


Figure A.11 Christchurch meshblock accessibility to GPs, moderate interpolation

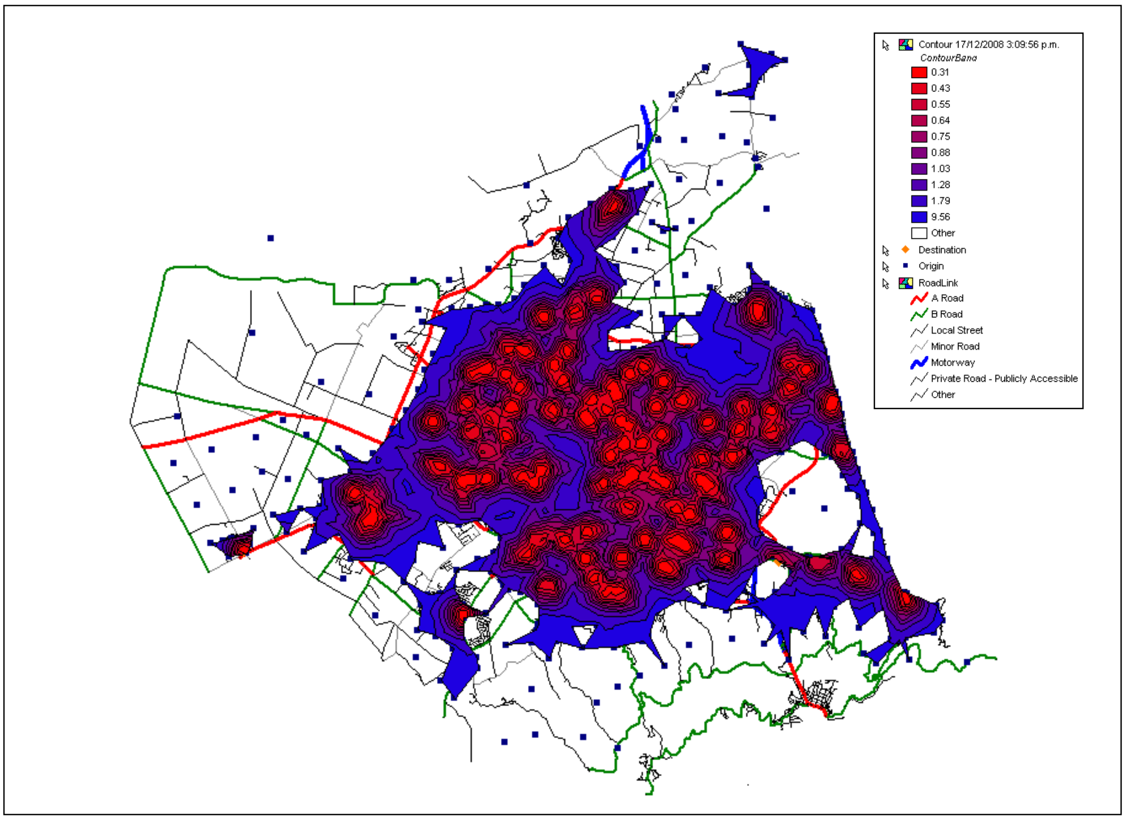
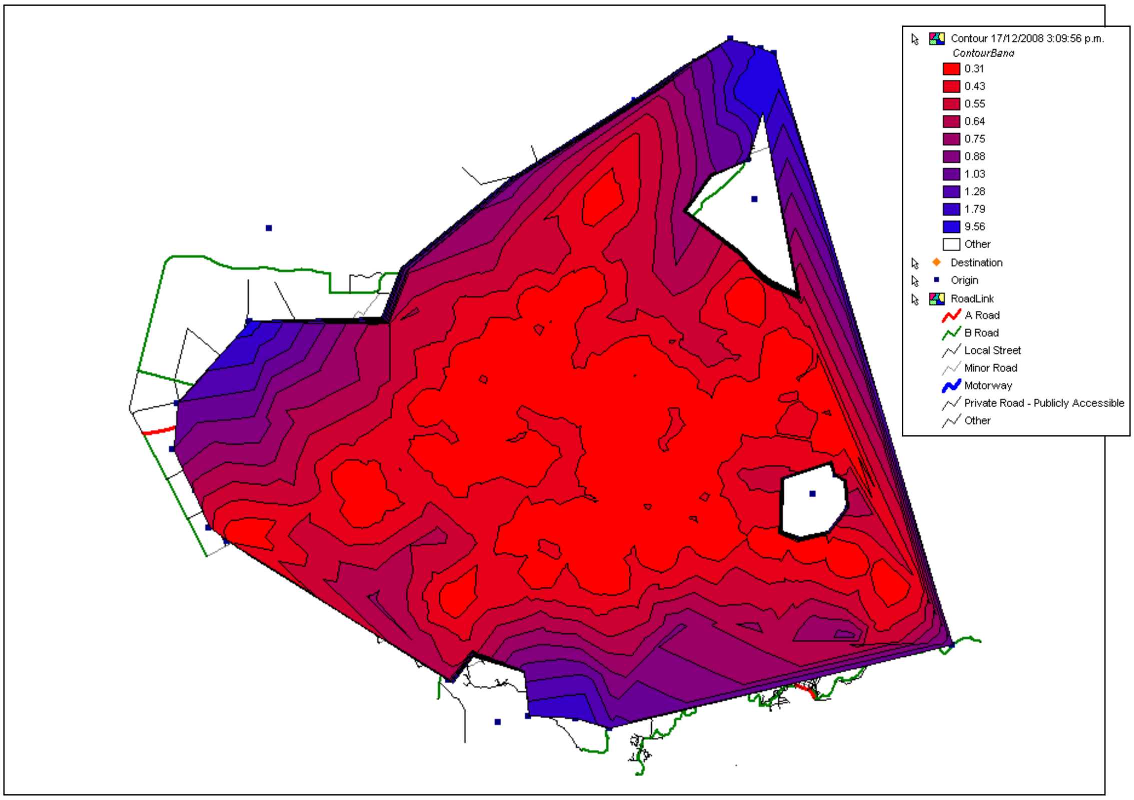


Figure A.12 Christchurch meshblock accessibility to GPs, relaxed interpolation



An analysis was performed on the same result set including geodemographic data to compare the accessibility of Christchurch with the 2007 DfT accessibility values. The population of each meshblock was used to perform a threshold analysis for accessibility to a primary health care provider by private vehicle.

Accession calculated 100% of the population of Christchurch has access to a primary health care provider by private vehicle within 15 minutes. As a general comparison, the UK DfT indicator 'Percentage of households within 15 and 30 minutes of a GP by public transport/walking' for 2007 was measured as 98.3%. No meaningful comparison can be made between these two indicators because they relate to two different modes. The UK uses public transport and the simplified Christchurch model uses private motor vehicle. Therefore as a sensitivity test, a five-minute threshold was used which showed 99% of the Christchurch population has access to a primary health care facility by private vehicle.

This analysis demonstrates the use of meshblocks for geodemographic data. Christchurch shows little difference in levels of accessibility when using a modified DfT indicator. The use of individual household data would enable a more detailed accessibility analysis to be undertaken given the finer grained nature of walking, cycling and public transport networks compared with the private vehicle network.

Even so, this assessment may still be limited because the average vehicle speed was set to the UK default of 49km/h. The assumption of such a high constant speed through an urban road network does not reflect the real world situation where intersections, deceleration, acceleration and congestion delays reduce average speeds significantly from posted speed limits. The average vehicle speed reflective of an urban environment is probably closer to 30km/h.

A4.4 Discussion

Presenting the accessibility to general practitioners by meshblock using contours shows Accession has correctly identified that the meshblock centroids which are closer to general practitioners have a higher accessibility than those further away. Lower contour values (shown in red on figures A.10 to A.12) represent origins with a lower cost of access to general practitioners and therefore higher accessibility, while higher contour values (shown in blue) represent origins with a higher cost of access to general practitioners and therefore lower accessibility.

Testing the three interpolation options (aggressive, moderate and relaxed) indicates visual results can be heavily influenced by the interpolation type. Aggressive interpolation is more appropriate to use when results datasets have a high quantity of origin points. Relaxed interpolation is more appropriate when the dataset has sparse data points as origins.

The result sets shown in figures A.8 to A.10 do not include geodemographic data such as the population attributes of each meshblock. The results only use the OD matrix travel time values. A meshblock with high accessibility to a general practitioner is desirable, but if the population of the meshblock is very low, then the benefit of greater accessibility to the community is limited.

Further results can be calculated through the inclusion of geodemographic data. These results provide much richer information in terms of assessing and therefore potentially optimising a population's access to an activity. Undertaking an analysis to determine the number or percentage of population within 'accessible' reach of particular activities or land uses provides a better assessment of accessibility.

The accessibility analysis using Accession does not consider the reach to multiple opportunities. This is a significant limitation of the simplified 'closest facility approach' used by Accession to assess accessibility.

It would be an interesting exercise to fully develop an Accession model for Christchurch including all modes, in particular, public transport and walking, and then compare the model results with the UK DfT indicators.

Appendix B: Neighbourhood accessibility assessment – council resources survey

ABOUT YOU

Name:		
Position / Job title:		
Organisation:		
Contact details:	Phone:	Email:

ABOUT YOUR GIS STAFF

GIS structure	Department Based	Corporate Service	Both	N/A
Number of dedicated GIS staff	0	1-4	5-10	>10
Do you have the resources to produce custom GIS applications			Yes	No
Comments:				

ABOUT YOUR TRANSPORTATION STAFF

Transportation staff structure	Department Based	Corporate Service	Both	N/A
Number of dedicated transportation staff	0	1-4	5-10	>10
Comments:				

ABOUT YOUR GIS RESOURCES

Do you run internet map services			Yes (Internet)	Yes (Intranet)	No
If yes, which service do you run	ArcIMS	ArcGIS Server	Mapserver	MapXtreme	Other
Desktop GIS software used: Circle all that apply or write comments below:		ESRI	ArcView	ArcEditor	ArcInfo
		MapInfo	MapInfo Professional		
		Intergraph	GeoMedia		
		AutoDesk	MapGuide		
		Other:			
Common operating system: (desktop computers)		Windows	Vista	XP	2000

	Other:			
Hardware capability: (desktop computers)	Processor	< 2Ghz	2-3Ghz	> 3Ghz
	RAM	< 1GB	1-2Gb	> 2Gb
Comments:				

ABOUT YOUR GIS DATA

Do you have the following data: Please include comments on the extent to which your data has been geocoded						
Public bus data	Yes	No	Source	Captured by your organisation		
Circle all that apply or write comments below:				Received from others:		
			Data includes	Routes	Stops	Sections
				Timetable	Other:	
			Data quality	High	Medium	Low
			Maintenance	Frequent	Infrequent	Nil
Commuter train data	Yes	No	Source	Captured by your organisation		
Circle all that apply or write comments below:				Received from others:		
			Data Includes	Routes	Stops	Sections
				Timetable	Other:	
			Data quality	High	Medium	Low
			Maintenance	Frequent	Infrequent	Nil
Cycle network	Yes	No	Source	Captured by your organisation		
Circle all that apply or write comments below:				Received from others:		
			Data Includes	Routes & paths		Intersections
				On-road	Off-road	Cycle Racks
				Travel Times	Other:	
			Data quality	High	Medium	Low
			Maintenance	Frequent	Infrequent	Nil
Ferry service data	Yes	No	Source	Captured by your organisation		
Circle all that apply or write comments below:				Received from others:		
			Data Includes	Routes	Ports	Timetable
				Other:		
			Data quality	High	Medium	Low
			Maintenance	Frequent	Infrequent	Nil

Pedestrian access data	Yes	No	Source	Captured by your organisation		
Circle all that apply or write comments below:				Received from others:		
			Data Includes	Routes & paths		Crossings
				On-Road	Off-Road	Travel Time
				Rest Points	Other:	
			Data quality	High	Medium	Low
			Maintenance	Frequent	Infrequent	Nil
Land use or zoning	Yes	No	Comment:			
Road hierarchy	Yes	No	Comment:			
Land parcels	Yes	No	Comment:			
Vacant land parcels	Yes	No	Comment:			
Land activity use	Yes	No	Comment:			

ABOUT YOUR TRANSPORTATION DATA

Do you have the following data: Please circle all applicable responses and comment where appropriate						
RAMM inventory	Yes	No	Comment:			
Traffic flows	Yes	No	Comment:			
Does your organisation run a macro transport model				Yes Town / City wide	Yes Regional / District wide	No
If Yes, please answer the remainder of the survey about your network model(s)						
Model structure			Large model		Multiple small models	
What modes are included in the model			Classic 3 Step 4 Step		Other:	
What year is your model validated to						
What future year models do you have						
Who maintains your transport model			Internal	External Consultant		Both
What software is your model run on			emme/2	Tracks	Trips	TransCAD
			Saturn	Other:		
Is your model linked to journey planning					Yes	No
What roads are included in your model			All roads		Major roads only	
			All roads except local		Selected strategic roads	
What zone system is used in the model			Greater than area unit		Area unit	

	Area unit - meshblock	Meshblock
	Other:	
What trip generation is used in the model	Data from own city / town	Data from another city / town
Comments:		

ABOUT JOURNEY PLANNING

Does your organisation run online journey planning services	Yes	No
If yes, what software do you use to run journey planning services		
Was this software customised prior to implementation	Yes	No
Please provide further details about your jounrney planning services below:		

Thank you for your time and input, please return this form to us in the self addressed envelope provided.

Appendix C: New Zealand Household Travel Survey

C1 Introduction

The analysis of deterrence parameters made use of the New Zealand Household Travel Survey (NZHTS) database supplied from the Ministry of Transport (MoT) (dated 25 February 2011). This section provides a description of the NZHTS, as extracted from section 2 of *NZ Transport Agency research report 353* 'National travel profiles part A – description of daily travel patterns' (Abley et al 2008).

C1.1 About the New Zealand Household Travel Survey

The NZHTS is a series of travel surveys designed to provide a databank of personal travel information for New Zealand. It is part of a continuous survey that began in 2003 and is designed to be useful in enabling identification of long-term travel trends. This databank will continue to be an important source of information to influence government policies and monitor transport and safety performances. The Ministry of Transport (MoT 2007) states 'the aim of this survey is to increase our understanding of travel behaviour by people in New Zealand, including travel by car as a driver or passenger, walking and cycling'.

The current travel survey differs from the previous one-off surveys conducted in 1989/90 and again in 1997/98 in that the survey is now continuous rather than discrete. Discrete surveys are not as reliable in developing valid estimations of changes in accident risks and travel patterns occurring over time. The continuous survey ensures the availability of up-to-date travel data to formulate new transport and road safety policies.

C1.2 Survey procedure

The NZHTS dataset analysed in this report includes travel by approximately 35,000 people from some 12,800 households in sample areas throughout New Zealand between 2003 and 20010. The NZHTS is administered by an independent contractor, on behalf of MoT, who sends selected households an initial letter which includes a pamphlet briefly describing the aims and content of the survey.

The interviewer then calls at the address to gather household information, explains the purpose of the survey and informs the household which days are their 'travel days'. The travel days are two consecutive days for which the household records all travel. The two consecutive days may be two consecutive weekdays or weekends. An even spread according to the day of the week is maintained by systematic allocation of travel days. The survey includes trips beginning between 4am on day 1 to 3.59am on day 3, a 48-hour period. Respondents are given a memory jogger to use for recording travel. The survey is voluntary. The response rate calculated in 2003/2004 was 64% (MoT 2007).

Finally, the interviewer returns to conduct the interviews as soon as possible after the travel days. A detailed description of the NZHTS methodology can be found on the MoT website.[13]

C1.3 Data description

This research relies on a household travel survey undertaken in 14 local government areas in New Zealand. Between March 2003 and June 2010, 40,161 people were interviewed from 21,588

[13] www.transport.govt.nz/research/Pages/TravelSurvey-Method.aspx

households; of these 34,311 people from 12,814 households generated valid responses. The data was supplied by MoT dated 25 February 2011. In general, the data is collected in the categories shown in table C.1. This report only focuses on analysing the trip data to determine deterrence parameters. The 'trip' variables supplied by MoT are listed in section C2.

Table C.1 Main data categories and descriptions

Main data category	Description
Household	Details about the household and its response to the survey
Person	Details about people in the household (information such as age, gender, experience, accident totals, occupation, income, driving, and work and school locations)
Trip	Purpose, mode, date, time, distance of each trip leg and vehicle information
Vehicle	Type, make, model, year, engine CCs and owner information for vehicles driven during the survey
Alcohol	Drinking session times and locations
Accident	Accident involvement over the last two years
Address	Text description of trip destinations
Accident locations	Text description of accident locations
Trip geocoding	Trip location (map references) and geocoded distance estimates
Address geocoding	Address location (map references)

The survey was geographically stratified using Statistics New Zealand definitions from the 1996 Census of Population and Dwellings[14]. The strata were based on the 14 local government regions, further stratified into main urban areas (MUAs) which have a population of at least 30,000; secondary urban areas (SUAs, which have a population between 10,000 and 30,000; and rural areas (RAs) which include minor urban areas with populations less than 10,000 and all other rural areas.

The sample sizes within local government regions were proportional to 2001 Census populations except the initial survey emphasis was as follows:

- less than proportional: Auckland, Canterbury, Wellington
- more than proportional: Hawke's Bay, Nelson/Marlborough, Northland, Southland, Taranaki, Gisborne and the West Coast regions.

C1.4 Definition of trips and purposes

The definition of 'trip legs', 'modes' and 'trip purposes' can often vary between countries. The perception of these terms and how the terms are applied in practice also varies between research documents. The *Travel survey report 1997/1998* (LTSA 2000) used trip legs to understand New Zealanders' travel behaviour. O'Fallon and Sullivan (2005) used 'trip chains' to understand how New Zealanders linked their travel into journeys. Consequently, it is important to define these terms to understand the results

[14] www.stats.govt.nz/statistical-methods/default.htm

contained in this report. This allows practitioners to understand how the travel profiles are generated, and allows for comparisons with other national and international research.

The analysis in this report uses 'trip legs' and 'trip leg purposes'. The 'trip data' contains over 108,200 separate rows, one for each trip leg. The Ministry of Transport (Abley et al 2008) defines a trip leg as:

> *A trip leg is a section of travel by single mode with no stops. Thus if one walks to the bus stop, catches the bus to town and walks to his/her workplace, he/she has completed three trip legs (home-bus stop, bus stop 1 to bus stop 2, bus stop 2-work).*

Off-road travel, such as on off-road tracks or around private property (eg farms) were excluded from the survey. All on-road travel, including farmers' work travel, was included in the survey criteria.

Each trip leg has a trip leg purpose and the trip legs contained in the database are categorised by the 'Tractiv' column. This column provides details of what activity is undertaken at a trip leg destination. Fifteen activities [trip leg purposes] are listed:

1. **Home:** This is used where the person is returning home, or to a temporary place of residence at the end of a trip leg.
2. **Work – main job:** This indicates trip legs to work at a fixed work address. The main job is the job at which most hours are worked.
3. **Work – other job:** This is used to describe trip legs to a secondary or other job at a fixed work address.
4. **Work – employer's business:** This describes all work-related stops that are not to a fixed work address. Employed or self-employed people without a fixed place of work (eg plumbers) are included in this category.
5. **Education:** This includes travel as a student to institutions such as primary and secondary schools, colleges of advanced education, technical colleges, universities etc. This also includes school-related activities that are not at school, eg school outings, school patrol or school sports in school time. Sports at the weekend or after school are coded as 'Recreation'. This does not include trip legs to pre-school care/education facilities, as these are considered to be 'Social/entertainment'.
6. **Shopping:** This describes any trip leg ending at premises which sell goods or hire goods out for money. Premises which provide services only (eg solicitors, banks) or repairs only (eg appliances or shoe repairs) are coded as 'Personal business/services'. Shopping is defined as any time the respondent enters a shop, whether or not a purchase is made.
7. **Social welfare:** This includes stops made at government agencies involved in welfare, eg Work and Income, guidance counsellors, employment offices, etc and also includes collecting pension or unemployment benefit cheques. In this report, however, trips that fall under this definition are included in 'personal business/services' unless otherwise stated.
8. **Personal business/services:** This includes stops made to transact personal business where no goods are involved, eg banks, hairdressers, laundromats, libraries, veterinary surgeons, government offices other than social welfare agencies (eg city councils and voluntary work).
9. **Medical/dental:** This includes any stop made for personal medical or dental needs. Stops made by a respondent who is accompanying another person are coded under the purpose of 'Accompany[ing] someone else'.

10 **Social/entertainment:** This includes visits to a private home; visits to a non-private dwelling (eg visiting a friend in hospital, visiting a friend staying in a hotel); pre-school activities such as kindergarten, crèche, day-care, kohanga reo or nursery school; and all entertainment activities occurring in a public or private place. Such entertainment activities include dining out, clubs, hotels, concerts, religious meetings and off-road driving or motocross. Walking or cycling for social purposes involve exercise and are therefore coded as ‘Recreational’.

11 **Recreational:** This includes participation in sporting activities and travelling to sporting or recreational activities (eg driving to the park to go jogging). It excludes watching someone else play sport, which is ‘Social/entertainment’; and off-road driving or motorcycling, which are coded as ‘Social/entertainment’ as these have no exercise component.

12 **Change mode:** This records all cases where the purpose of the stop was to change to another mode of transport.

13 **Accompany someone else:** This is used in cases where the purpose of the travel was to go somewhere for someone else’s purpose. This is usually to pick up, drop off or accompany another person (or persons) eg a parent who walks to school in the afternoon to pick up their children

14 **Left country:** This is used where the respondent leaves New Zealand during the travel days. Their travel while in New Zealand should be recorded but any travel outside New Zealand does not form part of the study and is not recorded.

15 **Other:** This covers any other trip leg purposes not defined by the preceding trip leg definitions above.

C2 Trip data variables

Variable name	Description
Year	Survey year number 1=2002/03 2=2003/04 3=2004/05 4=2005/06
Samno	Sample number
Person	Person number
Yearnm	Survey year name (in format 200203, 200304 etc)
hhdate1	First travel day
hhdate2	Second travel day
Hhdaywk1	Day of week of first travel day (Sunday=1)
Hhdaywk2	Day of week of second travel day (Sunday=1)
Daywk	Day of week of the travel day this trip takes place on (Sunday=1). Based on hhdaywk1 and hhdaywk2
Tripday	Trip day
Tripno	Trip number
Trleave	Departure time
trleaveh	Departure time in hours with decimal (+24 if next day)
trleavetm	Departure time, SAS time format
Trleavenextday	Departure time is next day (after midnight and before 4am)
Traddno	Destination address number
Trarriv	Arrival time
Trarrivtm	Departure time, SAS time format
Trarrivh	Departure in hours with decimal (+24.00 if next day)
Trnextday	Arrival time is next day
Duration	Duration of trip (hours)
Durmin	Duration (minutes)
Tractiv	Activity – what is done there 1 = Home 2 = Work – main job 3 = Work – other job 4 = Work –employer's business 5 = Education 6 = Shopping 7 = Social welfare 8 = Personal bus./services 9 = Medical/dental 10 = Social visits 11 = Recreational 12 = Change mode

Variable name	Description
	13 = Accompany someone else 14 = Left country 15 = Other
Purpose	Overall journey purpose, where a journey is a series of trips with purpose = change mode. Same codes as tractiv
Tripstart_activ	Origin of this trip leg (see also jstart). Coding is as for tractiv, except that for first trip of day tripstart_activ is based on pe1strt/ pe2strt. 99= Other from pe1strt or pe2strt (ie not home, work main, work other, social/rec, or hosp/ med).
Vehicle	Vehicle number
Trmode	Travel mode 1 = Vehicle driver 2 = Vehicle passenger 3 = Bicycle 4 = Train 5 = Bus 6 = Ferry 7 = Plane 8 = Taxi 9 = Other 10 = Mobility scooter 0 = Walk
trmodeother	Travel mode other
trquickest	Quickest route taken
trmidaddno	Route taken address no
Trdistn	Reported distance in km
Trpeopl	Number of people in vehicle
Trwpark	Where parked 1 = Not parked 2 = Off street – resident's property 3 = Off street – private 4 = Off street – public 5 = On street – time limit 6 = On street – no time limit 7 = Other
trwparkother	Where parked other
Trroads	Number of roads crossed
Trpedes	Number of pedestrian crossings used
startaddno	Start address number
tractivother	Activity other
CalculatedDistance	Critchlows calculated distance
calcdist	Same as CalculatedDistance but easier to type
BestDist	Best available distance – calculated dist if credible, else estimated dist (see note 1 for definition of 'credible distance estimate'

Variable name	Description
distused	Indicates which distance estimate used for analysis Geodist = CalculatedDistance Estdist = Respondent estimated distance (trdistn) Neither = both distance sources failed criteria, bestdist and duration set to missing BadGeo = should not arise – means do not use calculated distance but no alternative explored
Trip_comments	Method of calculation for the trip Q = Quickest route W = Waypoint used X = Waypoint provided but not used N = Trip not generated
Vyear	Year of manufacture
Vtype	Body type 1 = Car/station wagon 2 = Van/ute/passenger van 3 = 4-wheel drive 4 = Truck 5 = Taxi 6 = Motor bike 7 = Other
Vcc	Engine capacity
Vowner	Vehicle owner 1 = Member of household 2 = Company owned/leased 3 = Rental 4 = Other
Vfuel	Vehicle fuel 1 = Petrol 2 = Diesel 3 = LPG/CNG 4 = Dual fuel 5 = Electric 6 = Other
area2	**Missing if hhweight is missing** CENTR = Central Auckland MUA = Main urban area NORTH = Northern Auckland SOUTH = Southern Auckland WESTE = Western Auckland rural = Rural This is the variable for stratum2
Areatype	**Missing if hhweight is missing** 'Urban' = Main urban areas 'Rural' = Rural areas and secondary and minor urban areas

Variable name	Description
	****NB the previous definition of this was wrong! Secondary urban areas are NOT included within the 'Urban' definition***** Preferable to use AREATYPE2
Areatype2	'MUA' = Main urban areas (pop 30,000 or more) 'SUA' = Secondary urban area (pop 10000 – 29,999) 'Rural' = Rural areas and rural centres (pop<1000) MoT believes this also includes minor urban areas with pop 1000 – 9999
Journey	Journey number, where journey is one or more legs linked by change mode
legno	Number of this leg within journey
numlegs	Total legs in this journey
jdestn	Activity or purpose - same codes as tractiv
jmode	All modes used in this series of change mode trips
jarriv	Arrival time of final leg (hours and decimal fractions of hours)
jleave	Departure time of first leg (hours and decimal fractions of hours)
jstart	Activity or purpose at origin of first leg (ie of previous trip)
jtime	Journey duration

C3 References

Abley, S, M Chou and M Douglass (2008) National travel profiles part A – description of daily travel patterns. *NZ Transport Agency research report 353*. 150pp.

Land Transport Safety Authority (LTSA) (2000) *Travel survey report 1997/1998*. Wellington: LTSA.

Ministry of Transport (MoT) (2007) *Preliminary results of household travel survey 2003–2004*. Wellington: MoT.

O'Fallon, C and C Sullivan (2005) Trip chaining: understanding how New Zealanders link their travel. *Transfund NZ research report 268*.

Appendix D: Walking network attribute values

D1 Building field definitions

Attribute value	Description
BRIDGE	Walking links along bridges
C2	Public parks of city-wide significance which help provide the city with its unique scenery and character.
C4	Most of the cemeteries that are currently operating. Cemeteries that have significant heritage value are zoned in C2 to provide greater recognition of their historic values.
CARPARK	Private car parks.
CARPARK_PUBLIC	Public car parks
CU4	Campuses of tertiary education facilities.
FOOTPATH	Footpath walking links.
O1	Small areas of public open space which are of value to local neighbourhoods and communities.
O2	Large areas of public open space for active recreation which serve a suburban or district-wide function.
O3	Large public recreation areas, may be associated with areas of open parkland.
OPEN AIR MALL	Malls such as New Brighton or Bishopdale that are pedestrian access only.
RIVER	Walking links alongside rivers.

D2 Intersection field definitions

Attribute value	Description
LIGHTS	Road crossing links at intersections controlled by traffic signals.
REFUGE	Road crossing links that traverse through pedestrian refuges, recorded along public bus routes only.
ROAD	Road crossing links at intersections not controlled by traffic signals and within district centres.
ZEBRA	Road crossing links over zebra pedestrian crossings.

Appendix E: Weighting matrices

E1 Mode weightings by activity type and age group

The relative importance of each transportation mode to each age group, based on land use facility was given a weighting so accessibility from a particular location could be combined into comprehensive accessibility scores. When the land use facility was considered non-relevant to the age group in question, all mode weightings were set to zero.

Table E.1 Age group: 0–4 years

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.10	0.05	0.25	0.60
Hospital	0.05	0.00	0.35	0.60
Primary school	0.00	0.00	0.00	0.00
Secondary school	0.00	0.00	0.00	0.00
Further education	0.00	0.00	0.00	0.00
Convenience store	0.00	0.00	0.00	0.00
Supermarket	0.00	0.00	0.00	0.00
Work	0.00	0.00	0.00	0.00

Table E.2 Age group: 5–9 years

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.10	0.05	0.25	0.60
Hospital	0.075	0.025	0.275	0.625
Primary school	0.30	0.10	0.25	0.40
Secondary school	0.00	0.00	0.00	0.00
Further education	0.00	0.00	0.00	0.00
Convenience store	0.50	0.30	0.10	0.10
Supermarket	0.00	0.00	0.00	0.00
Work	0.00	0.00	0.00	0.00

Table E.3 Age group: 10–19 years

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.20	0.10	0.30	0.40
Hospital	0.10	0.05	0.35	0.50
Primary school	0.30	0.10	0.20	0.40
Secondary school	0.15	0.25	0.35	0.25
Further education	0.25	0.25	0.25	0.25
Convenience store	0.40	0.40	0.10	0.10
Supermarket	0.20	0.15	0.25	0.40
Work	0.25	0.25	0.25	0.25

Table E.4 Age group: 20–24 years

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.20	0.10	0.30	0.40
Hospital	0.10	0.05	0.35	0.50
Primary school	0.00	0.00	0.00	0.00
Secondary school	0.00	0.00	0.00	0.00
Further education	0.25	0.25	0.25	0.25
Convenience store	0.40	0.40	0.10	0.10
Supermarket	0.20	0.15	0.25	0.40
Work	0.25	0.25	0.25	0.25

Table E.5 Age group: 25–64 years

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.20	0.10	0.30	0.40
Hospital	0.10	0.05	0.35	0.50
Primary school	0.00	0.00	0.00	0.00
Secondary school	0.00	0.00	0.00	0.00
Further education	0.25	0.25	0.25	0.25
Convenience store	0.40	0.40	0.10	0.10
Supermarket	0.20	0.15	0.25	0.40
Work	0.25	0.25	0.25	0.25

Table E.6 Age group: 65 years and over

Activity	Transportation mode			
	Walking	Cycling	Public transport	Private vehicle
Doctor	0.25	0.05	0.40	0.30
Hospital	0.20	0.00	0.50	0.30
Primary school	0.00	0.00	0.00	0.00
Secondary school	0.00	0.00	0.00	0.00
Further education	0.20	0.10	0.40	0.30
Convenience store	0.50	0.10	0.20	0.20
Supermarket	0.175	0.025	0.50	0.30
Work	0.25	0.10	0.40	0.25

E2 Activity weightings by age group

Relative importance of each facility type to each age group. All rows total 1.00

Age group	Activity type						
	Doctor	Hospital	Primary school	Secondary school	Further education	Convenience store	Supermarket
0–4	0.80	0.20	0.00	0.00	0.00	0.00	0.00
5–9	0.20	0.05	0.60	0.00	0.00	0.10	0.05
10–19	0.05	0.05	0.10	0.55	0.10	0.10	0.05
20–24	0.10	0.05	0.00	0.00	0.40	0.15	0.30
25–64	0.15	0.10	0.00	0.00	0.20	0.15	0.40
65 & over	0.30	0.15	0.00	0.00	0.05	0.15	0.35

E3 Age group weightings

Relative importance of each age group to the final comprehensive accessibility score. Based on the age group's % of national population in the 2006 Census.

Age group (years)	0–4	5–9	10–19	20–24	25–64	65 & over
Work weighting	0.07	0.07	0.15	0.07	0.52	0.12

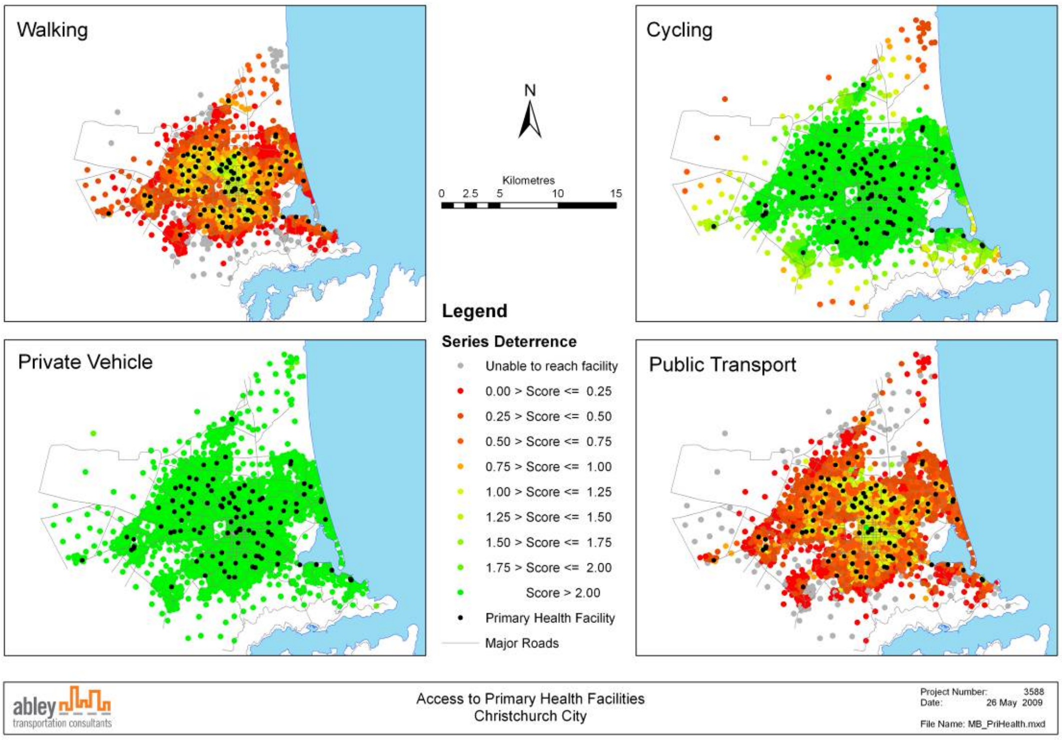
E4 Working age group weightings

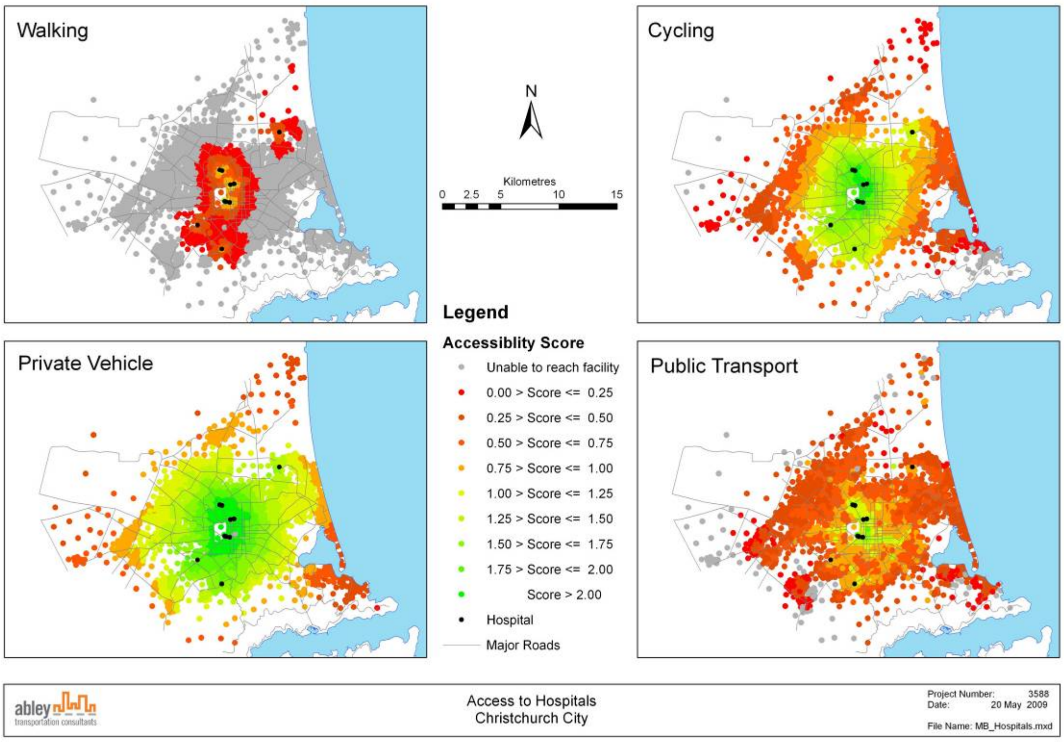
Relative importance of each age group to the final age-weighted sum of accessible work locations. Based on the age groups % of national population (aged 10 and over) in the 2006 Census. Note: the age groups 0–4 and 5–9 years old are considered to have no working members.

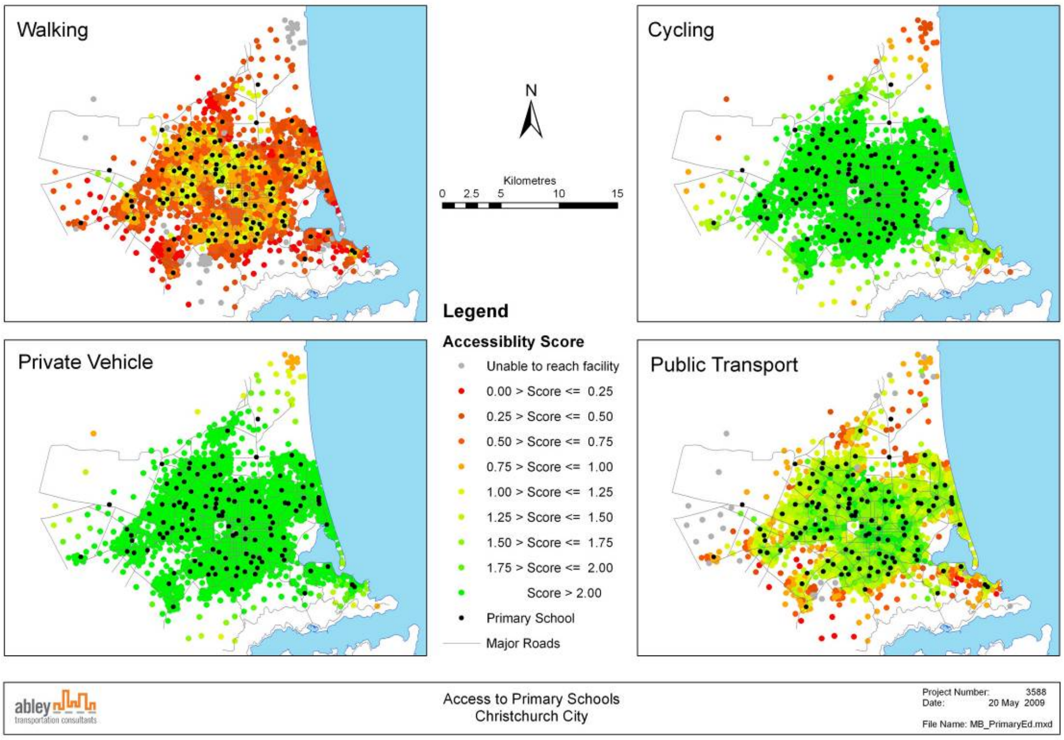
Age group (years)	0–4	5–9	10–19	20–24	25–64	65 & over
Work weighting	0.00	0.00	0.18	0.08	0.60	0.14

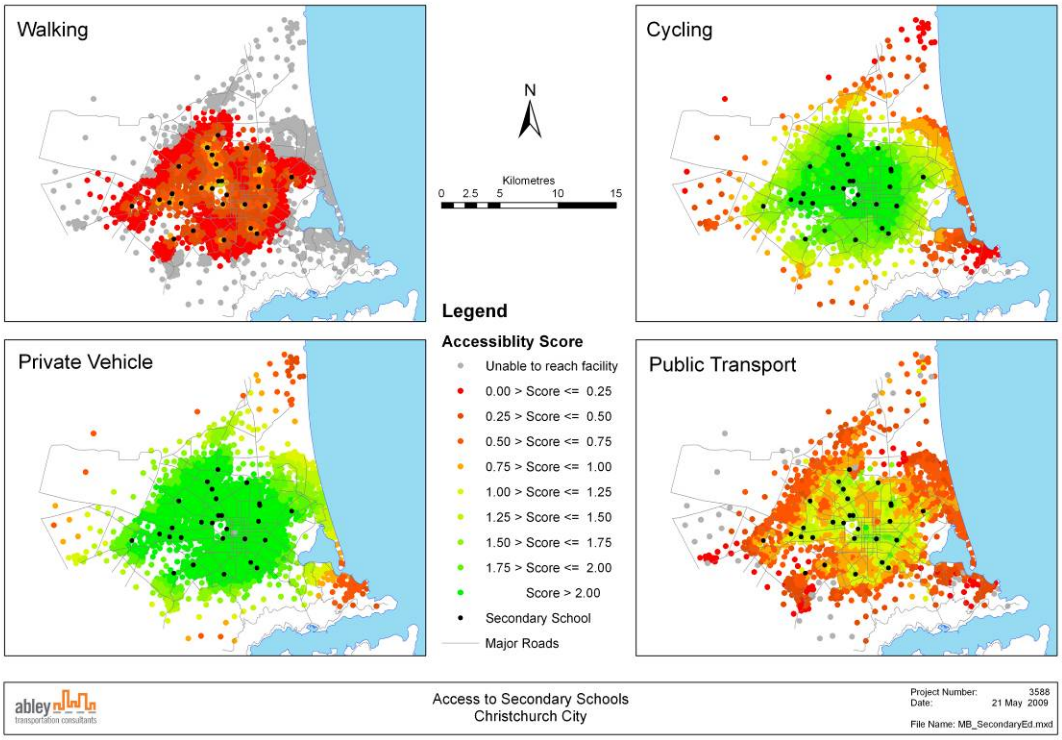
Appendix F: Case study outputs

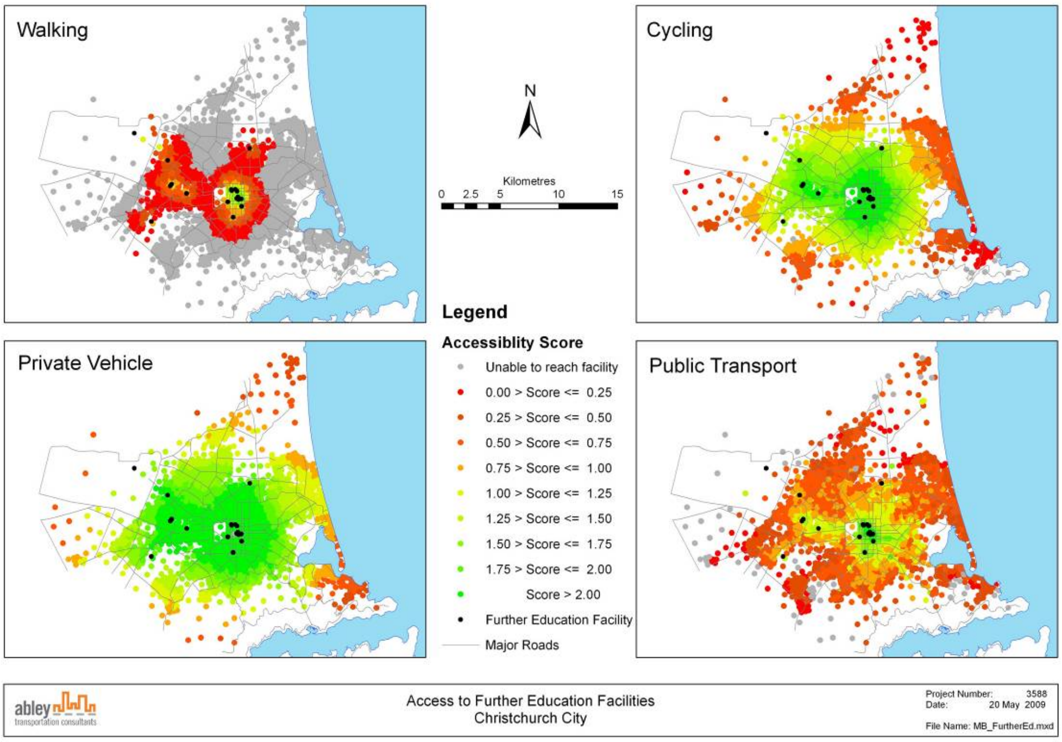
F1 Christchurch – meshblock level study



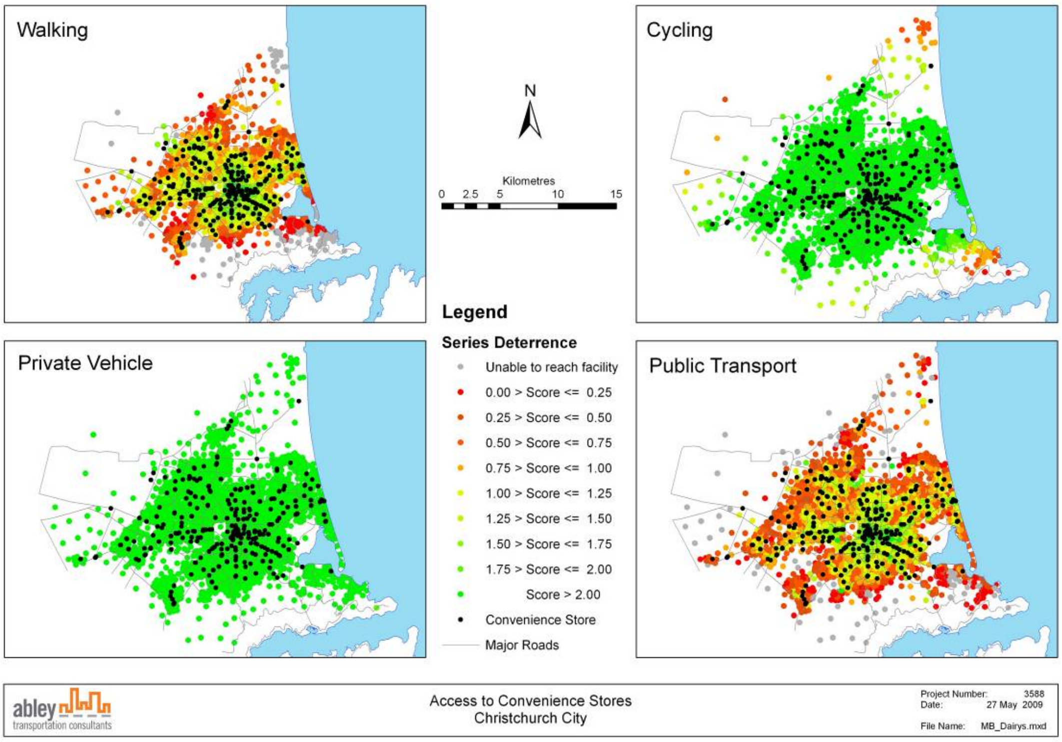



Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Accessiblity Score
Unable to reach facility
0.00 > Score <= 0.25
0.25 > Score <= 0.50
0.50 > Score <= 0.75
0.75 > Score <= 1.00
1.00 > Score <= 1.25
1.25 > Score <= 1.50
1.50 > Score <= 1.75
1.75 > Score <= 2.00
Score > 2.00
Primary School
Major Roads
abley transportation consultants
Access to Primary Schools
Christchurch City
Project Number: 3588
Date: 20 May 2009
File Name: MB_PrimaryEd.mxd

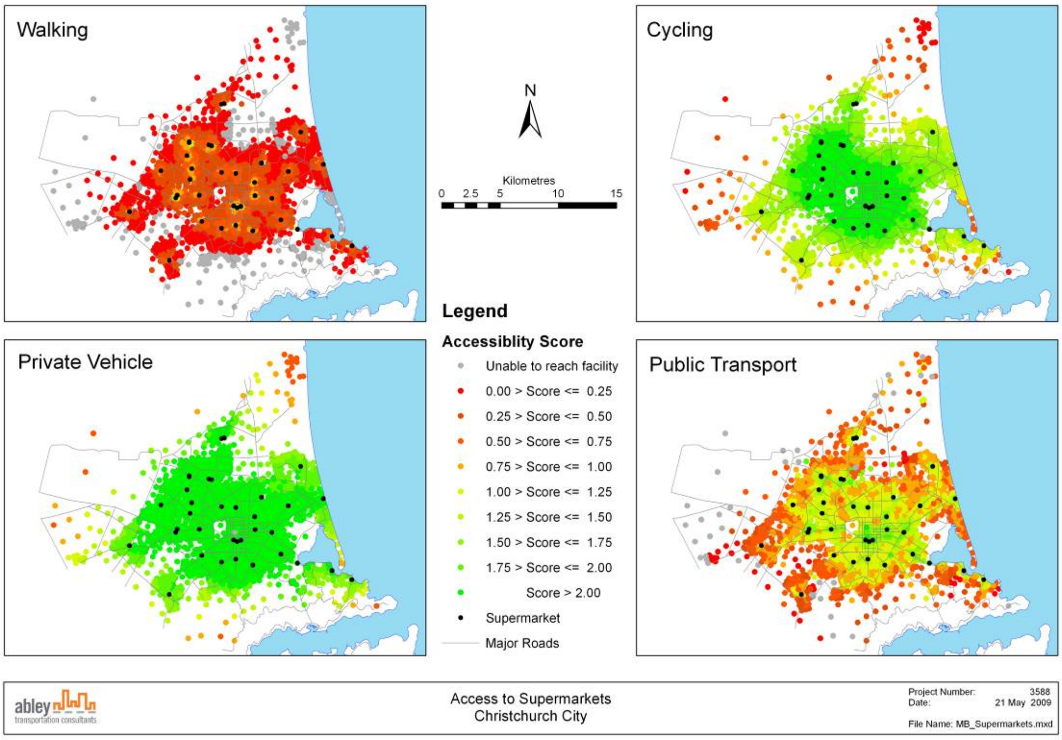

Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Accessiblity Score
Unable to reach facility
0.00 > Score <= 0.25
0.25 > Score <= 0.50
0.50 > Score <= 0.75
0.75 > Score <= 1.00
1.00 > Score <= 1.25
1.25 > Score <= 1.50
1.50 > Score <= 1.75
1.75 > Score <= 2.00
Score > 2.00
Secondary School
Major Roads
abley transportation consultants
Access to Secondary Schools
Christchurch City
Project Number: 3588
Date: 21 May 2009
File Name: MB_SecondaryEd.mxd

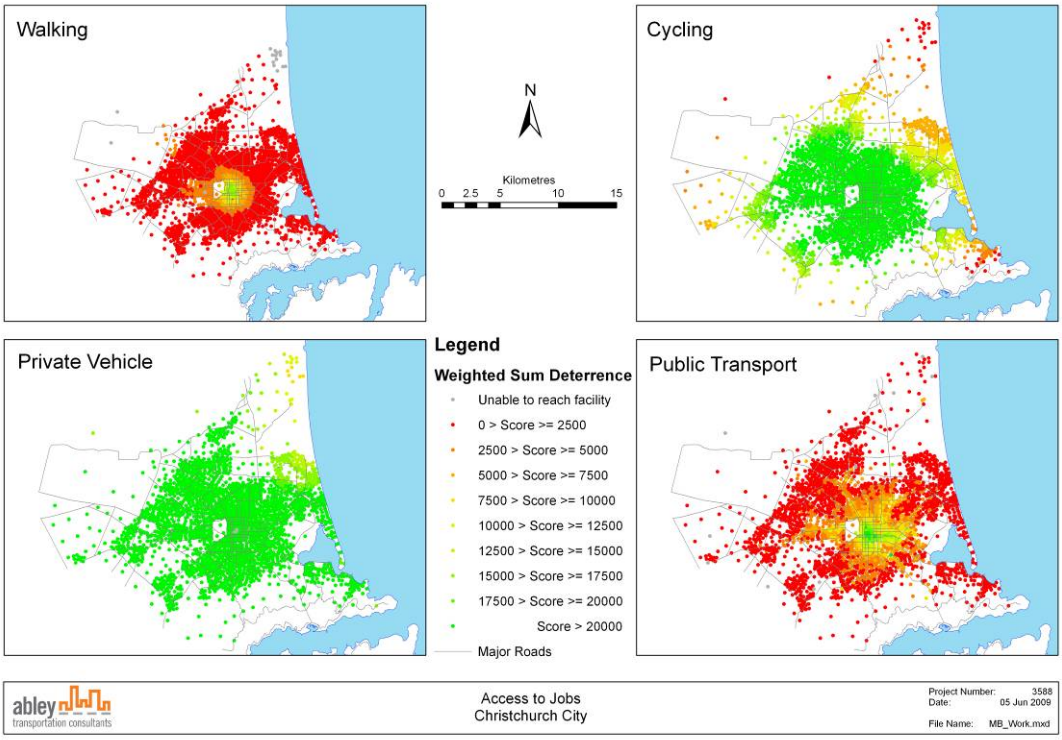


Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Accessiblity Score
Unable to reach facility
0.00 > Score <= 0.25
0.25 > Score <= 0.50
0.50 > Score <= 0.75
0.75 > Score <= 1.00
1.00 > Score <= 1.25
1.25 > Score <= 1.50
1.50 > Score <= 1.75
1.75 > Score <= 2.00
Score > 2.00
Further Education Facility
Major Roads
abley transportation consultants
Access to Further Education Facilities
Christchurch City
Project Number: 3588
Date: 20 May 2009
File Name: MB_FurtherEd.mxd

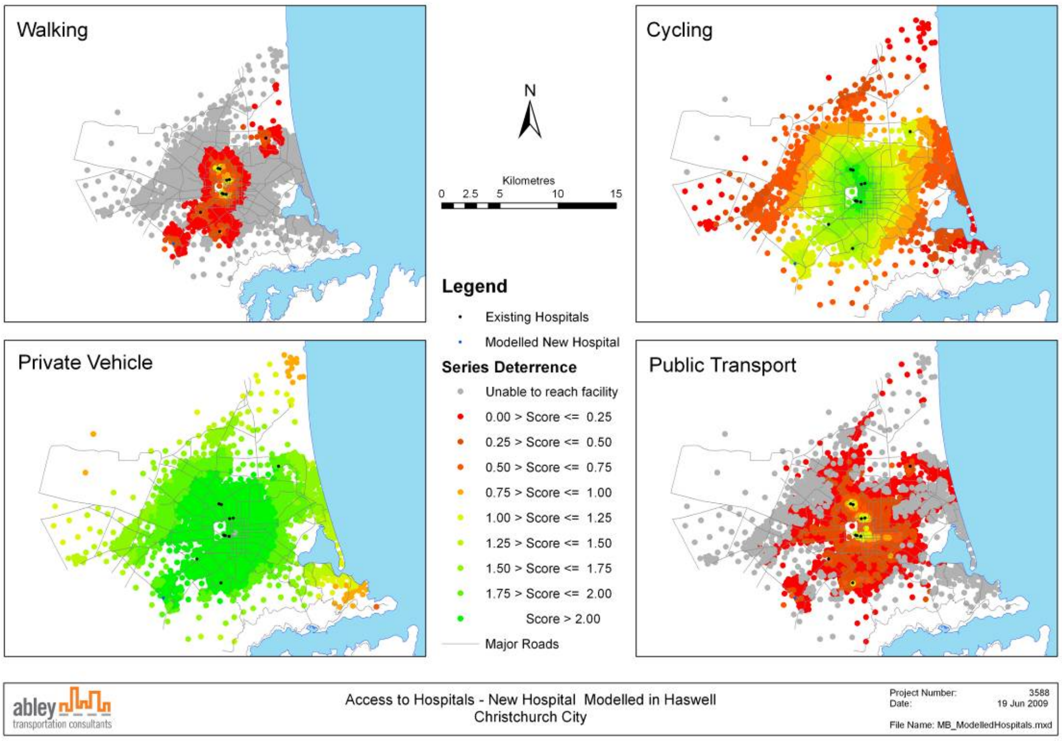


Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Series Deterrence
Unable to reach facility
0.00 > Score <= 0.25
0.25 > Score <= 0.50
0.50 > Score <= 0.75
0.75 > Score <= 1.00
1.00 > Score <= 1.25
1.25 > Score <= 1.50
1.50 > Score <= 1.75
1.75 > Score <= 2.00
Score > 2.00
Convenience Store
Major Roads
abley transportation consultants
Access to Convenience Stores
Christchurch City
Project Number: 3588
Date: 27 May 2009
File Name: MB_Dairys.mxd

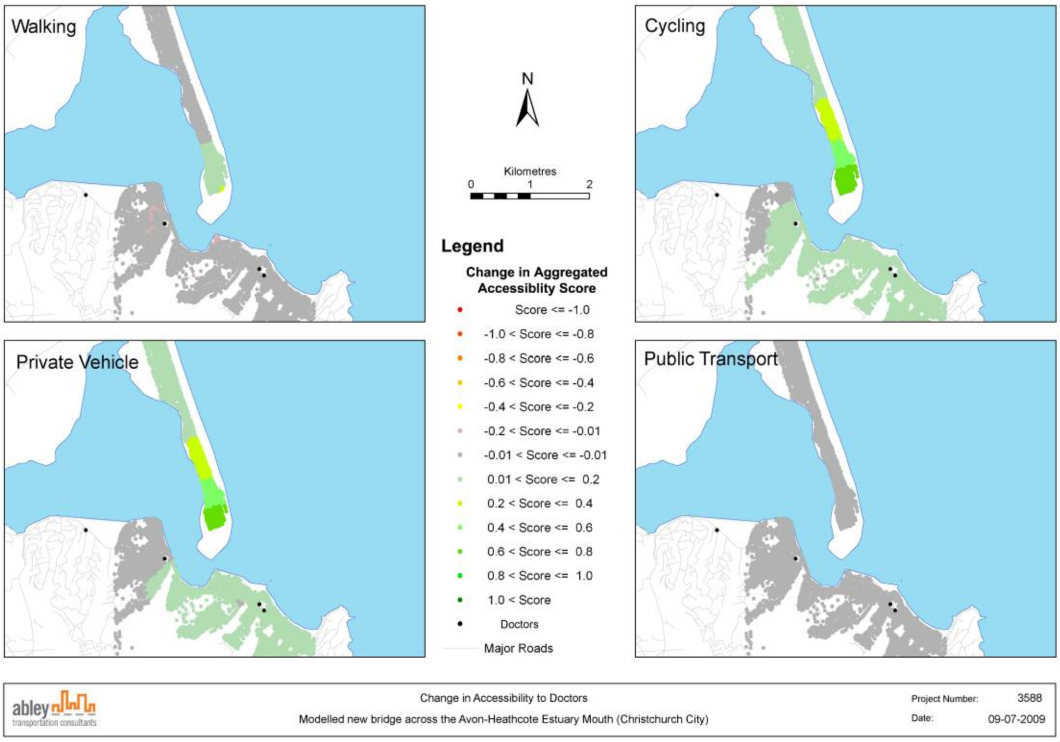

Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Accessiblity Score
Unable to reach facility
0.00 > Score <= 0.25
0.25 > Score <= 0.50
0.50 > Score <= 0.75
0.75 > Score <= 1.00
1.00 > Score <= 1.25
1.25 > Score <= 1.50
1.50 > Score <= 1.75
1.75 > Score <= 2.00
Score > 2.00
Supermarket
Major Roads
abley transportation consultants
Access to Supermarkets
Christchurch City
Project Number: 3588
Date: 21 May 2009
File Name: MB_Supermarkets.mxd

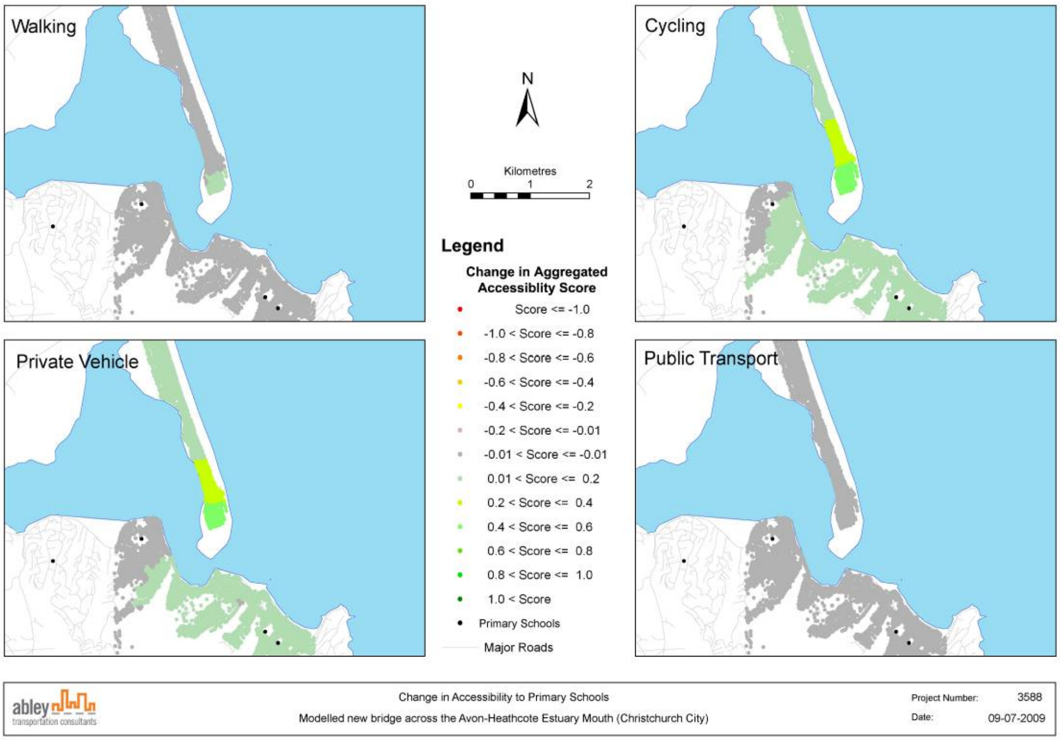

Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 2.5 5 10 15
Legend
Weighted Sum Deterrence
Unable to reach facility
0 > Score >= 2500
2500 > Score >= 5000
5000 > Score >= 7500
7500 > Score >= 10000
10000 > Score >= 12500
12500 > Score >= 15000
15000 > Score >= 17500
17500 > Score >= 20000
Score > 20000
Major Roads
abley transportation consultants
Access to Jobs
Christchurch City
Project Number: 3588
Date: 05 Jun 2009
File Name: MB_Work.mxd

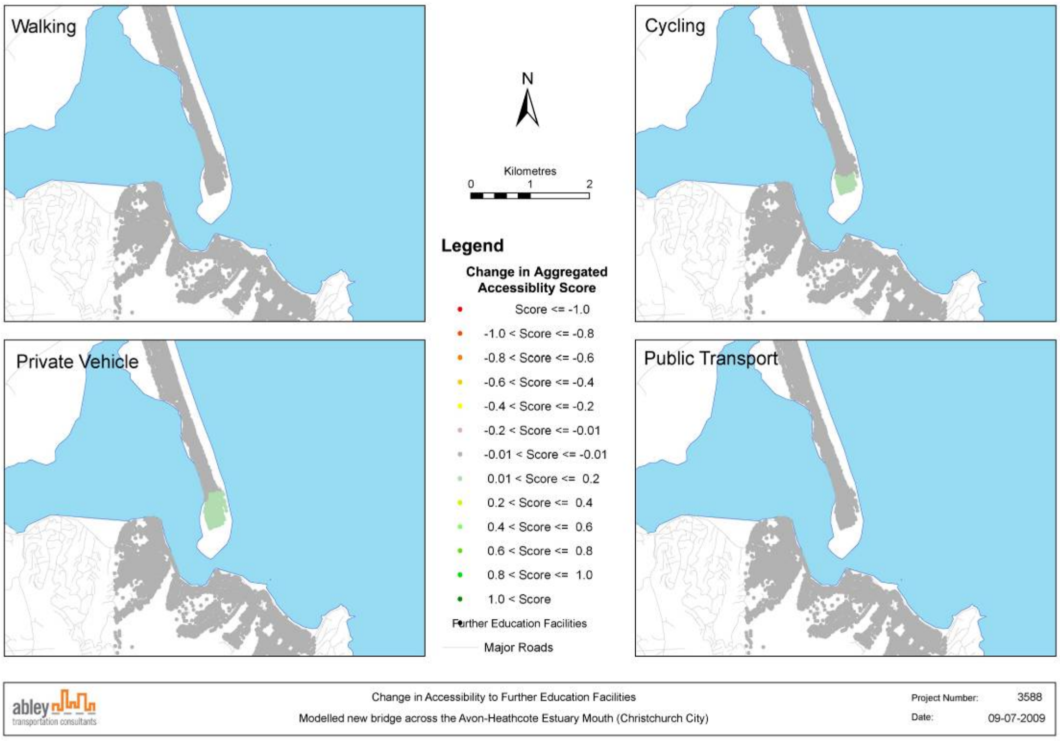
F2 Christchurch – modelled new hospital – meshblock level study

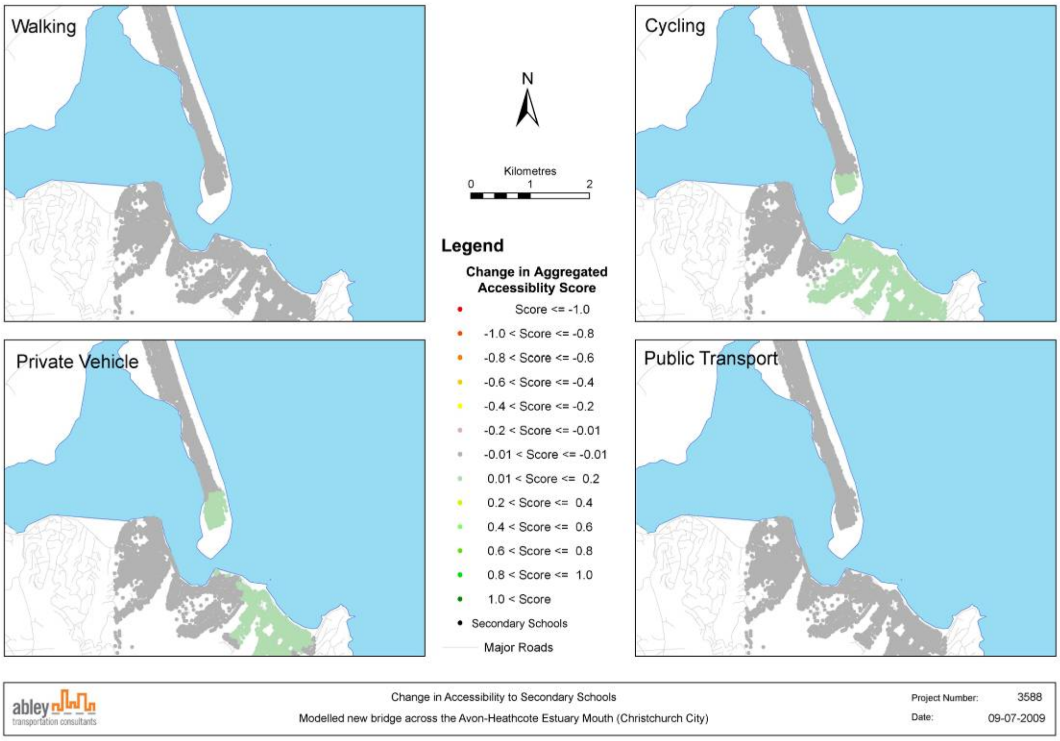


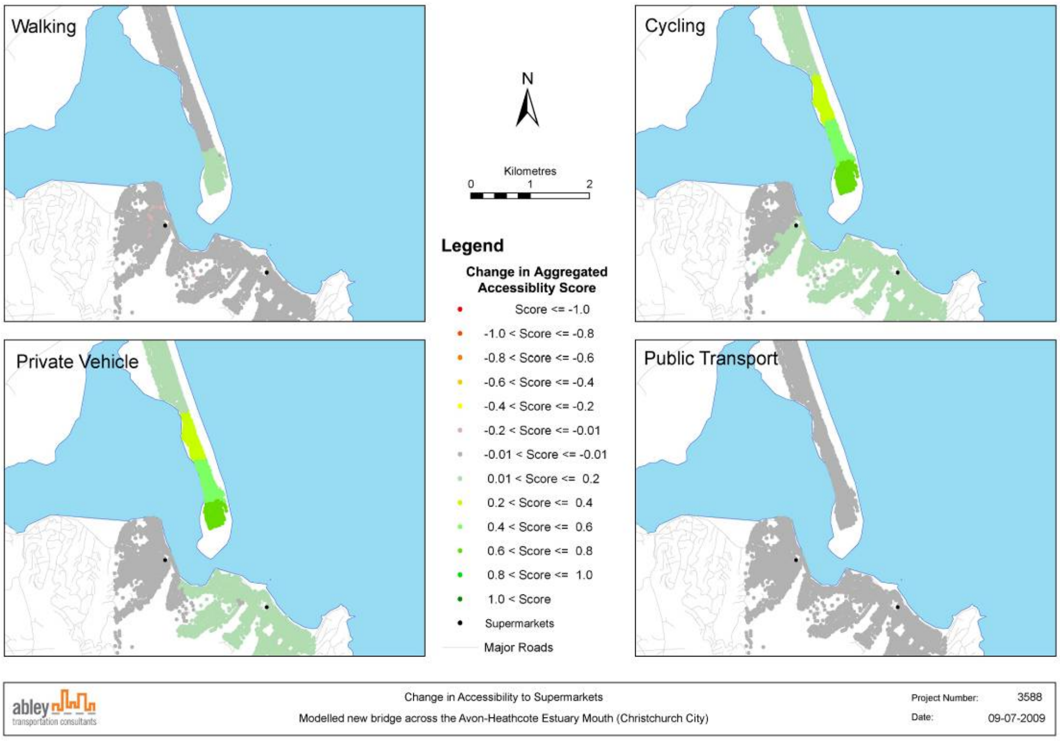
F3 Christchurch – change in accessibility resulting from new bridge across Avon-Heathcote Estuary – parcel level

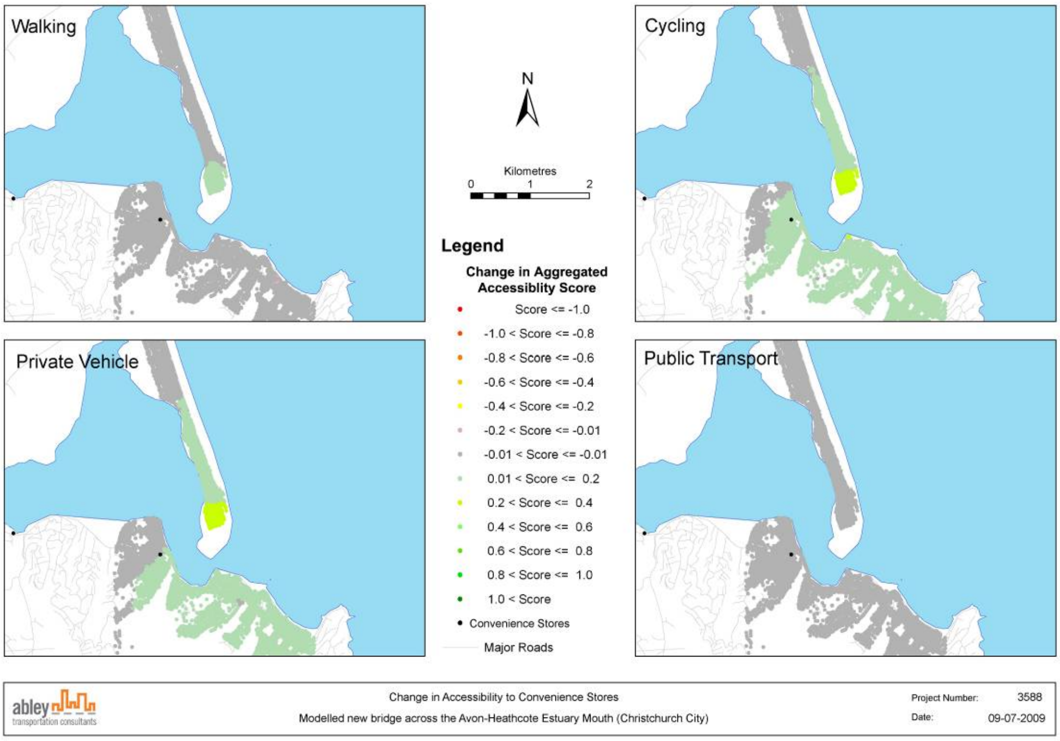





Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 1 2
Legend
Change in Aggregated Accessiblity Score
Score <= -1.0
-1.0 < Score <= -0.8
-0.8 < Score <= -0.6
-0.6 < Score <= -0.4
-0.4 < Score <= -0.2
-0.2 < Score <= -0.01
-0.01 < Score <= -0.01
0.01 < Score <= 0.2
0.2 < Score <= 0.4
0.4 < Score <= 0.6
0.6 < Score <= 0.8
0.8 < Score <= 1.0
1.0 < Score
Further Education Facilities
Major Roads
abley transportation consultants
Change in Accessibility to Further Education Facilities
Modelled new bridge across the Avon-Heathcote Estuary Mouth (Christchurch City)
Project Number: 3588
Date: 09-07-2009


Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 1 2
Legend
Change in Aggregated Accessiblity Score
Score <= -1.0
-1.0 < Score <= -0.8
-0.8 < Score <= -0.6
-0.6 < Score <= -0.4
-0.4 < Score <= -0.2
-0.2 < Score <= -0.01
-0.01 < Score <= -0.01
0.01 < Score <= 0.2
0.2 < Score <= 0.4
0.4 < Score <= 0.6
0.6 < Score <= 0.8
0.8 < Score <= 1.0
1.0 < Score
Secondary Schools
Major Roads
abley transportation consultants
Change in Accessibility to Secondary Schools
Modelled new bridge across the Avon-Heathcote Estuary Mouth (Christchurch City)
Project Number: 3588
Date: 09-07-2009


Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 1 2
Legend
Change in Aggregated Accessiblity Score
Score <= -1.0
-1.0 < Score <= -0.8
-0.8 < Score <= -0.6
-0.6 < Score <= -0.4
-0.4 < Score <= -0.2
-0.2 < Score <= -0.01
-0.01 < Score <= -0.01
0.01 < Score <= 0.2
0.2 < Score <= 0.4
0.4 < Score <= 0.6
0.6 < Score <= 0.8
0.8 < Score <= 1.0
1.0 < Score
Supermarkets
Major Roads
abley transportation consultants
Change in Accessibility to Supermarkets
Modelled new bridge across the Avon-Heathcote Estuary Mouth (Christchurch City)
Project Number: 3588
Date: 09-07-2009


Walking
Cycling
Private Vehicle
Public Transport
N
Kilometres
0 1 2
Legend
Change in Aggregated Accessibility Score
Score <= -1.0
-1.0 < Score <= -0.8
-0.8 < Score <= -0.6
-0.6 < Score <= -0.4
-0.4 < Score <= -0.2
-0.2 < Score <= -0.01
-0.01 < Score <= -0.01
0.01 < Score <= 0.2
0.2 < Score <= 0.4
0.4 < Score <= 0.6
0.6 < Score <= 0.8
0.8 < Score <= 1.0
1.0 < Score
Convenience Stores
Major Roads
abley transportation consultants
Change in Accessibility to Convenience Stores
Modelled new bridge across the Avon-Heathcote Estuary Mouth (Christchurch City)
Project Number: 3588
Date: 09-07-2009

Appendix G: Definitions and glossary

G1 Definitions

Name	Symbol	Definition	Equation
Age group adjusted composite accessibility score	$C_{Age\ Group}$	This combines all the age group adjusted multi-modal scores for the 7 consumed activity types, weighted according to the importance of each activity to the age group.	$C_{AgeGroup} = \sum_{1}^{i} M_i . AgeGroupActivityWeight_i$ i = number of activity types
Age group adjusted multi-modal score	$M_{Age\ Group}$	This incorporates all the aggregated accessibility scores for all modes of transportation, for each activity. The score for each transport mode is weighted according to its importance to each age group.	$M_{Age\ Group} = \sum_{1}^{k} S_k . AgeGroupModeWeight_k$ k = number of modes considered
Age-weighted sum of accessible work locations	W	This incorporates all the mode-weighted sum of accessible work locations scores for a site and weights each of these scores according to the fraction of the total working population which that age group comprises.	$W = \sum_{1}^{j} N_j . WorkAgeGroupWeight_j$ j = number of age groups
Aggregated accessibility score	S_{Mode}	This is the result of summing all the raw accessibility indices for a particular location, using a harmonic series. Each additional opportunity after accessing the first activity, contributes a smaller fraction of the one before it. Values > 1.00 imply that a particular location has multiple opportunities to access activities from it. There is an aggregated accessibility score for each transportation mode and activity combination. Note: Places of work are dealt with differently.	$S_{Mode} = \sum_{1}^{n} R_n / n$ n = number of paths
Comprehen-sive accessibility score	A	This incorporates all the age adjusted composite accessibility scores for a site and weights each of these scores according to the fraction of the total population which that age group comprises.	$A = \sum_{1}^{j} C_j . AgeGroupWeight_j$ j = number of age groups

Name	Symbol	Definition	Equation
Deterrence parameter	λ_{mode}	The parameter that describes the rate of decay of the deterrence function. The value differs with transportation mode and journey purpose.	
Mode-weighted sum of accessible work locations	$N_{Age\ Group}$	This incorporates all sum of accessible work locations scores for all modes of transportation, for the places of work. The score for each mode is weighted according to its importance to each age group when travelling to work.	$N_{Age\ Group} = \sum_{1}^{k} L_k .AgeGroupModeWeight_k$ k = number of modes considered = 4
Raw accessibility index	R	The percentage of people who would make a trip of at least time (t) to access the activity. Expressed as a number from 0.00 to 1.00. This is calculated from the journey time using a deterrence function.	$R = e^{-\lambda_{mode} t}$ t = time minutes
Sum of accessible employment locations	L_{Mode}	This is the result of summing all the raw accessibility indices for a particular location for employment locations. There will be a score for each transportation mode.	$L_{Mode} = \sum_{1}^{n} R_n$ n = number of paths
Time	t	The time in minutes to complete a journey from an origin to an activity.	

G.2 Glossary and abbreviations

Name	Description
Abley	Abley Transportation Consultants. A consultancy firm based in New Zealand that was commissioned to develop the New Zealand accessibility methodology.
Access	The achievement of reaching an activity.
Accessibility	The ease with which activities, either economic or social, can be reached or accessed by people
Accession	Accession is an accessibility tool produced by Citilabs UK.
AI	Accessibility index
API	Application programming interface. This is a source code interface that an application provides and allows a program to communicate with another program running in the same environment.
ArcGIS Desktop	The primary desktop GIS software product produced by ESRI.
ArcGIS Server	An integrated server based GIS for use with ArcGIS products.
ArcIMS	An ESRI program that allows for the publication of maps, data and metadata over the internet. ArcIMS is no longer in production and has been replaced by ArcGIS Server.
ArcGIS Network Analyst	An extension for ArcGIS. Network Analyst allows for vector network spatial analysis to be undertaken, including routing, closest facility, service area and travel direction analysis.
ArcObjects	A library of software components that make up the foundation of ArcGIS.
ARTA	Auckland Regional Transport Authority. This has now been combined with the transport expertise and functions of eight local and regional councils to become Auckland Transport.
ATM	Automated teller machine
AutoPTpath	A model created by the company Automatica and used in the United Kingdom. It is a routing algorithm which identifies the shortest path in a network.
Capability'	The ability of people to use the transportation network, eg being licensed to drive and having access to a vehicle enables people to use the road network
Capital	A calculator for public transport accessibility in London.
CBD	Central business district
Core+ activities	This is an extended version of the six activities recommended by the Social Exclusion Unit for use as the core measures for determining accessibility. The 8 Core+ activities are: • doctors (general practitioners) • hospitals • supermarkets • convenience stores (dairies, petrol stations) • primary schools • secondary schools • further education • employment (This is the only activity considered to have a heterogeneous level of service) The additional core activities include the consideration of primary and secondary schools as two separate measures and the inclusion of convenience stores.
Core indicators	A set of common measures designed to reflect the overall state of accessibility.
CRS	The core record system (CRS) managed by Land Information New Zealand, is the system for recoding and storing official spatial data. It is designed to assist in the digitisation of title and survey information. Terralink use a combination of CRS data and additional data sets to

Name	Description
	provide a comprehensive GIS dataset for commercial use.
Deterrence function	A function which describes how a barrier to transportation affects the number of people using that transport mode.
DfT	Department for Transport in the United Kingdom.
DHC	Derek Halden Consultancy. A consultancy firm based in the United Kingdom that was commissioned to provide a literature and modelling review of accessibility assessment in New Zealand.
ECAN	Environment Canterbury, the trading name of the Canterbury Regional Council.
Edge	In a node-edge vector model, the edges are the straight lines between the intersections (nodes) on the network. The modelled traffic travels along (traverses) these edges to get from A to B.
EDN	ESRI developer network. This is an annual subscription-based program that provides software developers with the resources needed to build solutions that embed ESRI desktop and server technologies.
ESRI	Environmental Systems Research Institute. A company that specialises in GIS and mapping software. ESRI produces the ArcGIS suite of products.
GIS	Geographic information system. A GIS is generally a computer system which is able to integrate, store, edit, analyse, share and display feature information that is geographically (spatially) referenced.
GPS	Global positioning system. The system of GPS satellites allow for a GPS receiver to precisely determine its location, speed, direction and time.
GRASS GIS	Geographic resources analysis support system. An open-source GIS used for geospatial data management and analysis, image processing, graphic and map processing, spatial modelling and visualisation.
GUI	Graphical user interface. A GUI is a type of user interface which allows interaction with a computer using graphical icons, visual indicators or special graphical elements known as 'widgets'.
GWRC	Greater Wellington Regional Council
IMS	Internet map server. Mapping software designed to send maps across the internet.
Intergraph Geomedia	A type of commercial GIS software.
IPTIS	Integrated public transport information system. The only public journey planning software currently used in New Zealand.
KaMap	An open source project that provides a javascript API for developing web-mapping interfaces using MapServer.
LINZ	Land Information New Zealand. LINZ maintains and regulates Crown and private property rights and provides geographic information about New Zealand.
LTCCP	Long-term council community plan
MapBasic	A programming language for creation of additional tools and functionality for MapInfo GIS software.
MapInfo	A GIS software company.
MapInfo Professional	MapInfo's primary desktop GIS software product.
MapServer	An open source development environment for building spatially-enabled internet applications. It is not a full-featured GIS system, and allows for the rendering of spatial data for communication across the internet.
MapXtreme	A mapping application server produced by MapInfo allowing for the publication of maps and data to the internet.

Name	Description
MAXX	The brand name for the Auckland regional public transportation system.
MetLink	The brand name for the Wellington regional public transportation system.
Metro	The brand name for Christchurch city's public transportation system.
Mobility	The ease of moving through the various transportation networks. For example congestion on a highway often represents the level of mobility for vehicles.
ModelBuilder	An ArcGIS tool designed to provide a simple interface for creating, editing and running geoprocessing models.
MUA	Main urban area
NationalMap2	A vector dataset of locations including both natural and cultural features provided by Critchlow Limited.
Native tab file	A MapInfo based vector data storage format for storing the location, shape, and attributes of geographic features.
New Zealand Household Travel Survey (NZHTS)	An ongoing survey undertaken by the Ministry of Transport to provide data on personal travel of New Zealanders and identify trends in travel over time.
Node	In a node-edge vector model, the nodes are the points where one edge terminates, or two or more edges meet. They can be thought of as intersections (and dead ends) on the network, where a choice has to be made as to which route (edge) to follow (traverse) next.
NZGO	New Zealand Geospatial Office
NZTA	New Zealand Transport Agency
OD	Origin and destination
Opportunity'	the availability of a land- use activity or service. For example the presence of a supermarket provides an opportunity for shopping.
PTAL	Public transport accessibility levels
Python	A high level open source programming language. It is commonly used with ArcGIS for customisation and scripting of geoprocessing tasks.
RAMM	Road assessment and maintenance management. A comprehensive road asset management software tool produced by CJN Technologies Ltd.
Resource survey	A survey undertaken by Abley Transportation Engineers Limited which surveyed regional and local councils in New Zealand on GIS and transport resources.
RLTP	Regional land transport programme
RLTS	Regional land transport strategy
RouteFinder	A graphical user interface produced by RouteWare to give non programmers the ability to use RouteWare graphically. It can be used by both MapInfo and ArcGIS users.
RouteWare	A company which specialises in shortest path algorithms, web-based applications for routing and routing for MapInfo and ArcGIS users.
Routing J Server	MapInfo's network analysis product.
RTIG-XML	An XML protocol sponsored by UK DfT to allow distributed computers to exchange real-time information about bus services.
RW NET	RouteWare routing tools which are used to produce custom routing applications in ArcGIS and MapInfo.
SDK	Software development kit. This is a set of tools, methods and documentation which are used to develop applications on a software platform.
Search threshold	In order to limit processing time, a practical limit on network search distance was selected in

Name	Description
	order to perform the analysis. This was chosen as the time after which only 5% of people would make the journey to the activity (95th percentile). This maximum search time was calculated by rearranging the deterrence function equation and solving for t when the percentage was 5% (0.05). $t = -\ln(0.05) / \lambda$ t = time (minutes)
SEU	Social Exclusion Unit, UK
Shapefile	An ESRI branded vector data storage format for storing the location, shape, and attributes of geographic features.
SUA	Secondary urban area
TfL	Transport for London, the local government body responsible for most aspects of the transport system in Greater London.
TRACKS	New Zealand Transport planning software developed by Gabites Porter Consultants Ltd.
Transportation mode	The network across which the journey takes place: walking, cycling, public transport (including walking) and private vehicle.
TransXchange	The UK nationwide standard for exchanging bus schedules and related data.
TSP	The travelling salesman problem; a routing issue concerning optimisation of a route to visit multiple locations in one journey.