Assessing the value of public transport as a network
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Robyn Hyde and Dave Smith

Abley Transportation Consultants Limited, Christchurch

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NZ Transport Agency
Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
research@nzta.govt.nz
www.nzta.govt.nz

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An important note for the reader

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Executive summary

The development of a comprehensive mechanism for measuring the value of public transport is important to gain a greater understanding of existing networks and plan optimal future networks. Mechanisms for measuring the value of public transport in New Zealand are currently limited and generally only consider financial aspects. Peak services on high-frequency corridors with high patronage generally operate with high efficiency, while other services such as evening or feeder services typically have low fare box recovery, and low perceived efficiency but are likely to contribute to higher passenger numbers elsewhere across the network and in doing so will add value to the network as a whole.

This research sought to understand and appraise the additional incremental value that is added to a public transport network by services that in isolation may be comparatively inefficient. Through identifying and understanding the elements that influence the value of public transport, the research aimed to develop a more comprehensive approach to quantifying the broader economic and social impact of the removal or addition of network services. This would enable practitioners to more consistently measure the broader value of public transport, compare the benefits and costs of changes and assist with funding applications.

The specific objectives of the research were to:

- undertake a review of New Zealand and international literature to determine the elements that influence the value of a public transport service
- determine the best methodology for appraising the value of isolated services, considering their contribution to the wider network and the economic and social value of the service to the community
- improve clarity around the linkages and synergies between individual services, the community and the public transport network as a whole
- develop a framework to assist network planning decisions to understand and value the contributions of individual services, when assessing the impact of reduction/increase in services with low patronage, on the value of the public transport network as a whole
- provide input into the NZ Transport Agency funding assessment process by providing information on how to capture and value broader public transport benefits to be used for future benefit calculations when assessing public transport network reviews.

A review of national and international literature was undertaken to identify studies that might provide a methodology for appraising the value of isolated services, through considering their value to the wider public transport network as a whole. Relatively few studies focusing on network benefits were found; however, there were a number of sources that qualitatively discussed the various elements that influence and have an impact on the value of public transport either directly or indirectly. The factors identified include:

- network planning, the network effect and the value of connectivity
- the ‘first and last mile’ effect including the relationship and role of feeder services to the network, and the importance of walkability and walk access to complete the first and last mile of a journey
- economic benefits primarily from reduced private vehicle use
- public transport demand elasticities and option value
- direct user benefits from increased mobility and access to services, education and employment

- impacts on the total value generated by a public transport network including economic, social, health and mobility effects
- the impact of public transport on the environment
- the relationship between public transport and land use.

Stakeholder consultation provided useful insight into the existing mechanisms and resources available to measure network value and to understand how network review decisions were currently managed. There was general agreement by stakeholders that the value of low-volume services to the network as a whole, and how to include social elements, accessibility and connectivity was not well understood. Decision making was often constrained by resource and political sensitivities, and stakeholders unanimously agreed that an appropriate and easy to use methodology for valuing public transport networks that was useful and useable, would be helpful to inform network planning.

Integrated ticketing transaction data, general transit feed specification (GTFS) feeds, and census data were sourced to understand how they could inform the development of an appropriate methodology. Extensive geographic information system (GIS) spatial mapping and statistical analysis of these data sets was undertaken to identify trends and relationships, and determine the value of a network component, and how that component contributes to the network value. This was achieved through introducing two case studies. First, a proof of concept was developed for a hypothetical change in spatial coverage by isolating the last few kilometres of an existing service. By isolating the unique card IDs of public transport (PT) patrons who originated in this study area, their travel behaviour could be mapped and an understanding of the trips enabled and distanced travelled by these users across the wider network identified. These metrics informed the value of the end of a service to the greater network value. Second, a temporal proof of concept was developed. The temporal analysis followed a similar process, exploring the extent to which the data sets could be used to measure the value of evening services through isolating the users of evening trips, and identifying the other trips undertaken by these users on the wider network at other times of the day.

A methodology for calculating the benefits and costs of a change in service provision is presented by adapting NZ Transport Agency's *Economic evaluation manual* (EEM) simplified procedures. This recognises the additional value to the network of new trips and reflects accurate trip lengths rather than the default trip length values to provide a more representative evaluation across the network as a whole.

In addition to the economic assessment of a change in public transport service or coverage, this research considered the importance of less tangible elements and how their contribution to the value of the entire network could be measured. An assessment using a 'level-of-service' type approach to measure the social and accessibility impact of a change in service is recommended.

This research developed a framework from which practitioners can consider broader economic and social implications of a change in service provision that financially may be perceived as demonstrating very little value. The framework presents a more integrated network approach to support investment decisions and funding applications by modifying the EEM simplified procedures to account for the additional contribution to the network of a spatial or temporal change in service provision, through the consideration of the social value of a change in public transport provision. Two case studies are presented to demonstrate the application and modification of the EEM simplified procedures and social assessment.

The proof of concept developed in the research provides guidance, and using the case studies as examples, demonstrates the ability to develop an understanding of value of a service and the additional value it adds to the network and the community it serves. However, it is recommended that the decision lies with the public transport planner as to how the social and accessibility elements and many trade-offs are managed, taking into consideration community and political sensitivities.

This report also makes recommendations towards the implementation of the research and further general comments for additional consideration.

Abstract

The development of a comprehensive mechanism for measuring the value of public transport is important to gain a greater understanding of existing networks and plan optimal future networks. Mechanisms for measuring the value of public transport in New Zealand are currently limited and generally only consider financial aspects. Peak services on high-frequency corridors with high patronage generally operate with high efficiency, while other services such as evening or feeder services typically have low fare box recovery, and low perceived efficiency but are likely to contribute to higher passenger numbers elsewhere across the network and in doing so add value to the network as a whole.

This research explored the elements that influence the value of a public transport service and developed a framework that extends the NZ Transport Agency's economic evaluation procedures to consider the contribution of isolated services to the wider network value. This will enable public transport planners to measure broader social and accessibility values of public transport, in addition to economic value, and compare the benefits and costs of changes taking into consideration the many trade-offs, as well as community and political sensitivities.

1 Introduction

Abley Transportation Consultants was engaged to determine the economic value of public transport services as a network, and what additional incremental value was added to the network by services that might, in isolation, be comparatively inefficient.

A key strategic goal of the government is to improve the effectiveness and efficiency of public transport. A substantial amount of investment in recent years has gone into making efficiency gains through the implementation of electronic ticketing systems, bus lanes and traffic signal priority; however, farebox recovery is generally only high on high-frequency services. Other services with lower patronage, generate less farebox revenue but are likely to contribute to higher passenger numbers elsewhere across the network and in doing so add value to the network as a whole.

This research sought to understand and appraise the additional incremental value that is added to a public transport network by services that in isolation may be comparatively inefficient. The research aimed to develop an appraisal approach that assessed tangible economic value based on revenue and operating cost aspects of public transport provision, and additionally acknowledged the social impacts of a public transport service.

Through identifying and understanding the elements that influence the value of public transport, a more comprehensive approach can be taken to quantify the economic and social impact on the removal or addition of network services.

A greater understanding of economic values of levels of service (LoS) within the public transport network will benefit communities, improve network planning and funding assessment processes, and increase the efficiency of government investment in public transport.

The specific objectives of the research were to:

- undertake a review of New Zealand and international literature to determine the elements that influence the value of a public transport service
- determine the best methodology for appraising the value of isolated services, considering their contribution to the wider network and the economic and social value of the service to the community
- improve clarity around the linkages and synergies between individual services, the community and the public transport network as a whole
- develop a framework to assist network planning decisions to understand and value the contributions of individual services when assessing the impact of reduction/increase in services with low patronage on the value of the public transport network as a whole
- present case studies demonstrating the assessment framework
- provide input into the NZ Transport Agency (the Transport Agency) funding assessment process by providing information on how to capture and value broader public transport benefits to be used for future benefit calculations when assessing public transport network reviews.

1.1 Report structure

The report is organised as follows:

- Chapter 2 provides background for the research by summarising the New Zealand public transport operating environment.
- Chapter 3 presents the findings of a review of international literature to understand existing practice for valuing public transport networks, and specifically examines the factors that contribute to and influence the total value generated by the public transport network as a whole.
- Chapter 4 provides a summary of feedback from engagement with stakeholders.
- Chapter 5 presents an assessment approach for a component of a public transport network and considers the wider contribution to the public transport network and community
- Chapter 6 details the data sets collected to form the basis of a methodology for valuing a component of the network.
- Chapter 7 details the spatial and temporal analysis undertaken using these datasets.
- Chapter 8 demonstrates the application and modification of the Transport Agency's economic evaluation procedures to support a cost–benefit analysis of the value of a component of a public transport network.
- Chapter 9 presents a mechanism for assessing and recognising social and demographic aspects that contribute to the value of public transport.
- Chapter 10 presents a summary of research outcomes.

2 Background

2.1 New Zealand public transport operating environment

The purpose of this section is to provide a high-level overview of the New Zealand public transport operating environment. In New Zealand it is the responsibility of Auckland Transport[1] and regional councils to manage the delivery of public transport through contracting private operators to provide public transport using buses, trains and ferries. City councils are responsible for the provision and maintenance of the infrastructure and central government supports the provision of public transport through transport legislation, strategic direction, operating policies and investment in service and infrastructure provision

The primary legislation regulating public transport is the Land Transport Management Act 2003, the Land Transport Management Amendment Act 2013, and the Public Transport Management Act 2008, which set out the principles for public transport, registration of services, policy and contractual requirements as well as safety and licensing requirements.

Land transport investment strategy, national objectives, priorities for land transport and funding levels for land transport investment are set out in the *Government policy statement on land transport* (GPS) (MoT 2015) and managed by the Transport Agency through the National Land Transport Programme (NLTP) 2012–2015 and a range of operational policies. Public transport operating costs are met through the NLTP, local funding and fares, with an aim to achieve a recovery ratio of 50%. This facilitates a level of fares that reflect the level of private benefit to public transport users, while the subsidy levels encapsulate the benefit to road users, ratepayers, the wider community, environment and the economy (NZ Transport Agency 2015).

The Public Transport Operating Model (PTOM) effective from June 2013 provides the framework for planning, procurement and business development of urban public transport in New Zealand. It was put into effect to foster greater collaboration between councils and operators to support the government's goal to increase public transport patronage with less reliance on subsidy. The model uses a partnering approach to grow:

- the commerciality of public transport services and create incentives for services to be fully commercial
- confidence that services are priced efficiently and there is access to public transport markets for competitors. (MoT 2011)

The PTOM requires regional councils to segment their public transport networks into units and specify each unit in their regional public transport plan (RPTP). This has meant that PTOM implementation has been progressive over the last three years as policy and new PTOM contracts are entered into. Units are required to relate to an identified customer market and can operate either commercially or receive government subsidy. Commercial units are operated without direct public subsidy, and have a contract term of nine years. Bus public transport units procured under the partnering delivery model are fixed at 12 years for like-for-like transitional contracts, nine years for bus units procured through the open selection process and six years for bus units contracted using direct appointment.

Contractual performance standards ensure a consistent service across a network, and financial and extended contract length incentives are provided to encourage a high standard of service delivery and

[1] Auckland Transport is a council controlled organisation responsible for public transport in Auckland.

growth of commerciality of units so they can operate without subsidy in the long term (NZ Transport Agency 2013). The provision of public transport services requires significant capital investment by operators. Different units within a network will have both different capital and ongoing operating costs as well as potentially different contract terms reflective of procurement strategy under the partnering model.

3 Literature review

3.1 Introduction

A review was undertaken of New Zealand and international literature to understand the best methodology for valuing public transport networks and examining public transport impacts on the total value generated by the network as a whole. This chapter begins with an overview of attributing values to public transport, followed by a review of literature on:

- network planning, the network effect and the 'first and last mile' effect including the relationship of feeder services to the network
- the value of connectivity and the role of feeder services
- public transport demand elasticities and option value
- impacts on the total value generated by a public transport network including economic, social, health and mobility effects
- the impact of public transport on the environment
- the influence of public transport on residential growth, housing prices and development.

3.2 Valuing public transport

Veeneman and van de Velde (2006) define a public value as an element the government is required to uphold due to public demand. This requires the government to recognise the value's significance and to devote resources to it accordingly.

The GPS states the strategic direction for land transport in New Zealand is to drive improved performance from the land transport system by focusing on:

- economic growth and productivity
- road safety
- value for money.

3.2.1 Public values in public transport

Public transport funding is provided by the government to provide access and choice. The GPS also recognises there is a need for public transport to unlock the potential of urban areas by providing additional capacity on key corridors and a choice of ways to move around. Table 3.1 outlines the types of public values and their areas of impact. Type A values support the public transport user, type B values aim to support the desired effects of public transport, and type C values try to limit the undesirable effects. Type D and E values reflect the rules of conduct within the public transport and government sectors respectively.

Table 3.1 Public transport public values (source: Veeneman and van de Velde 2006)

	Profile	Examples
Type A	Vulnerable groups	• Accessibility (for partially handicapped) • Affordability (for the less well off) • Availability (for those living in more remote areas)
Type B	Positive externalities	• Economic development of urban areas • Mobility (general) • Quality of life (general)
Type C	Negative externalities	• Quality of life (impact of public transport) • Safety (other traffic) • Health (people living in the vicinity)
Type D	Functioning of the sector	• Quality (service provision) • Security (employee, customer) • Reliability (employer, carrier)
Type E	Functioning of the government	• Demographic legitimacy • Reliability (government) • Efficiency (use of public resources)

While considering the contribution of each of these values, acknowledgement of the competition between values for resources is likely to be required in determining the value of a public transport network.

3.2.2 Measuring public transport performance

Brown and Thompson (2008) explore measuring public transport performance in terms of service effectiveness or productivity to determine how many passengers are attracted to each kilometre of service. However, service effectiveness is also influenced by urban structure (population and employment density), and regional policies such as parking fees, public transport service and route structures, fare levels and information systems.

3.2.3 Public transport network vs public transport system

The distinction between the public transport network and the public transport system needs to be noted when valuing a public transport system and underlying network. A public transport system may be described as the overall physical complex of infrastructure, technology and information that provides opportunities for passenger movement within urban space. A public transport network by comparison describes the spatial and temporal relationship between the lines of connection provided by the system (Dodson et al 2011). A renowned example of this conceptual separation of network and system is the London underground shown in figure 3.1. This map demonstrates the connectivity between tube lines in abstract form and provides almost no indication of the operational character of the system such as vehicle mode or speed, line length or width, or any signalling or scheduling.

Figure 3.1 London Tube map (source: Transport for London 2015)

3.3 Network planning

Passengers on public transport networks are motivated by their desire to travel based on their understanding of a complete network. The critical network aspects from a patronage perspective are speed, frequency, connectivity and legibility of journey path options. Network planning is central to the creation of a strong and stable network structure that provides a seamless integrated and high frequency network of services between all areas of significant transport demand, rather than a series of individual routes serving a specified set of origin-destination pairs. This is because the value of the integration of public transport services synergises greater value than each service in isolation (Dodson et al 2011).

Four key network planning concepts are introducing in this section: network effect, network connectivity, feeder services and the last mile effect.

3.3.1 Network effect

The primary understanding of the network effect is described by Mees (2010) as occurring when public transport is able to mimic the flexibility of a road system by interlacing different routes and modes into a multi-modal network where transfers between different routes are nearly effortless.

Figure 3.2 The network effect (source: Nielson and Lange 2008)

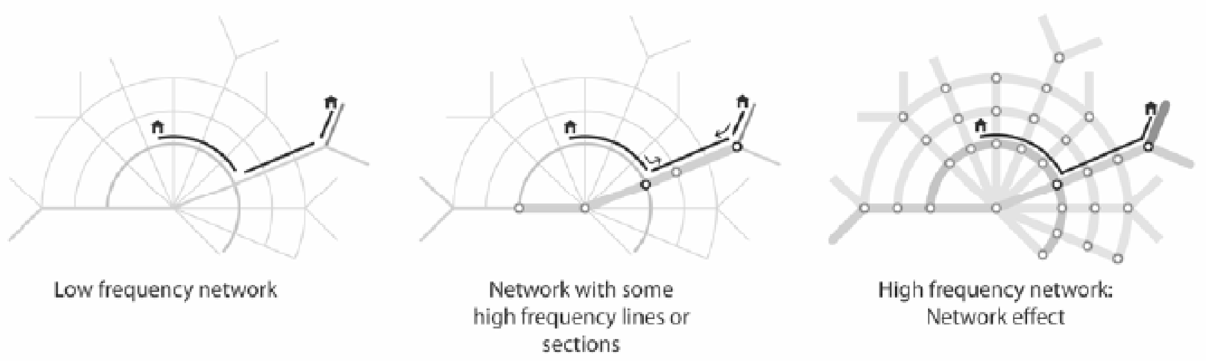


Figure 3.2 illustrates the network effect. The network effect centres on frequency and coverage of the public transport system. If services operate at low frequency, waiting times are long and if transfers are required it may not be the most desirable transport option. By contrast, higher frequency lines offer a system that competes with the car (Nielsen and Lange 2008).

The network effect is dependent on the assumption that passengers are willing to transfer, and the network and network infrastructure facilitate quality transfers. Transfers and delays in public transport networks are unavoidable as it is not possible to design a network where all passengers can travel directly from their origin to their destination. Careful network planning and scheduling are required to minimise transfer delay and enhance passenger value through seamless connectivity. A measure of the network effects for passengers can be estimated as the additional time (due to transfers) the passengers have to spend in the system. Network optimisation and the value of network effects can be obtained by comparing delays to passengers with the 'optimal timetable' (Landex and Nielsen 2007).

Mees (2010) theorises that the network effect can lead to patronage gains beyond those expected by conventional single-route cost-benefit analyses of public transport systems because of the demand enabled by seamless, ubiquitous, interconnected networks offering a wider array of transfer based trips. Dodson et al (2011) suggest that the principle of the network effect assumes that the marginal gain in demand exceeds the marginal cost of service improvement.

While a highly integrated, well-functioning network has a positive effect on demand and network value, the network effect can also have significant negative impact when areas of a network are subject to disruptions or delays. Network effect refers to the interdependencies of a public transport network, where a change or delay in one part of the network can influence other parts of the network – often far away from where the change occurred (Landex and Nielsen 2007). Network effects occur because train and bus routes are often long and have a high degree of reliance on mutual integration with infrastructure and road networks. The larger the network and the greater the number of connections or dependencies between vehicles, the greater the significance of network effects on public transport demand and value of the network (Nielsen and Lange 2008).

3.3.2 Network connectivity

Connectivity is the degree to which network components such as streets, railways, walking and cycling routes, services and infrastructure interconnect (Ministry for the Environment 2015). Public transport connectivity refers to the provision of services as part of an integrated network-based public transport system that offers choice and increased accessibility through door-to-door connections with minimum delay and seamless interchanges.

A passenger's decision to use public transport is based on their understanding of the spatial and temporal connectivity of the network (Dodson et al 2011). The most crucial advantage of a connective network is that it is simpler for users (Walker 2012). A value-of-time indicator can be used to understand the value of connectivity. For example, based on research by Douglas (2015), wait time is valued at twice that of in-vehicle time on high frequency services, therefore, the ability to move and connect to where you want to go within a network with minimum wait time is valued highly by patrons.

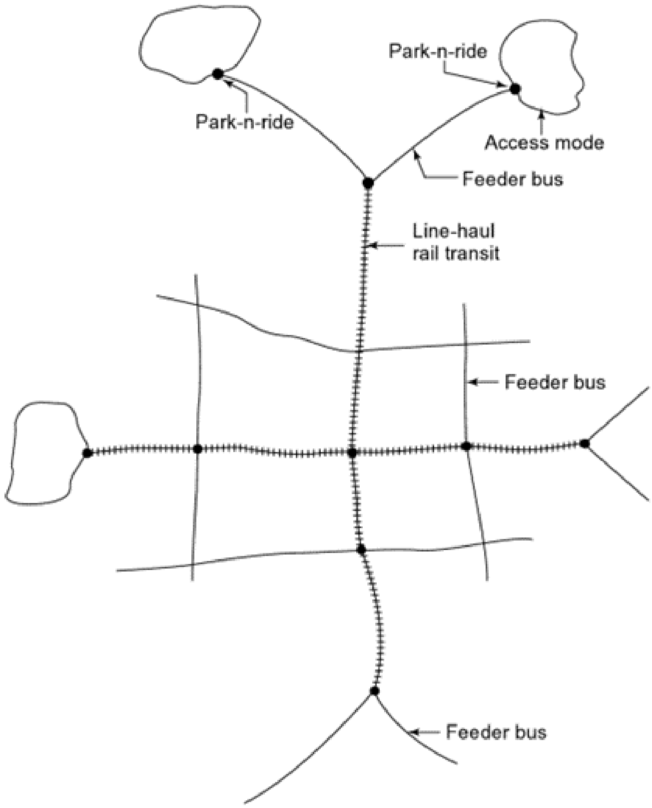
Public transport networks are systems of predetermined movement as travel demand is concentrated on corridors or routes. Users are able to enter, leave or transfer between routes but cannot make spontaneous decisions about changing direction in the way a pedestrian, cyclist or motorist can (Scheurer and Porta 2006). In this context, connectivity analysis of public transport must consider both spatial (route coverage, stop location and transfer availability) and temporal (waiting, travel and transfer time) components (Hadas et al 2014). A public transport network assessment can be used to derive the value of network connectivity or utility by interpreting a public transport route as a corridor of nodes linked by consecutive edges. The path along a public transport route has greater value within the network than a path of a similar distance that would require multiple transfers between different routes (Scheurer and Porta 2006).

3.3.3 Role of feeder services

The function of feeder services is to connect public transport users between origin and destinations to the main public transport routes in the network. Feeder services generally operate at a low frequency and are often used to provide connections between local suburbs and core high-frequency routes as shown in figure 3.3. Feeder services require a high degree of consistency, reliability and connectivity through careful network planning to offset the relatively low frequency of these services.

Feeder services may require users to transfer for most trips which means journey speeds are dependent on quick transfers. At a network level, fast and easy transfers that coordinate well with high-frequency trunk routes and pedestrian networks facilitate fast and reliable journeys to dispersed destinations within a public transport network. In effect the pedestrian networks are a feeder or extension of the public transport network as they have a role in collecting and distributing pedestrians to public transport services (Dodson et al 2011).

Figure 3.3 Relationship of feeder services to the rest of the network (source: Victor and Ponnuswamy 2012)



Feeder services are able to enhance the attractiveness of public transport through improved coverage which reduces walking and other access costs (ECONorthwest et al 2002). Feeder services are generally seen as having higher costs and lower ridership than the rest of the public transport network and can require long-term subsidies (Brake et al 2007). The main challenge of integrating feeder and core routes is how to increase network efficiency, specifically, the efficiency of feeder route design and coordinated schedules to minimise the cost of the services. With careful integration, the time taken for transferring between services becomes less, reducing the cost to the transit system, users and operator of the feeder service. The additional investment in feeder services increases the connectivity of the public transport and pedestrian networks and can lead to higher patronage and greater network value (Dodson et al 2011).

3.3.4 The 'last-mile' and 'first-mile' effect

The 'last-mile' effect is a term that has migrated from the business-to-customer logistics and telecommunications industries into transport planning and refers to the last-mile leading to a destination (Gronau and Kagermeier 2007).

In the context of public transport the primary meaning of 'first-mile' and 'last-mile' refers to the challenge of providing good connectivity to users for the entire length of their trip. An individual trip is considered to be the entire journey from origin to destination, which may necessitate a variety of transportation modes to complete. Chong et el (2011) assert that the public transport network should include provision of the first and last-mile to reduce extra time and hassle connecting from home to the network. A public transport system may provide the core of this trip but individuals must complete the first and last portion on their own, thus, the 'last-mile' effect concerns the provision of transportation from the nearest public transportation stop to a destination, usually the home or office (Wang and Odoni

2014). The unavailability of a transport service for the first-mile or last-mile is acknowledged as one of the main deterrents to the uptake of public transport, in particular, for the group known as the 'transport disadvantaged', predominantly children, the elderly and the disabled. It has also been suggested that the last-mile problem is one of the predominant factors contributing to society's inability to connect people with jobs.

The last-mile challenge is as much a function of land development patterns as it is of public transport, in essence, the easier it is to access the system the more likely people are to use it (The Central Maryland Transportation Alliance 2014). Bike racks on buses and the provision of services such as Park and Ride, Uber, Car2Go and bike share programmes can help ease the last mile effect for some people in some conditions. Improving access by active transport modes has also been cited as an effective solution to combat the first and last-mile problem, as people will bike or walk to public transport when it is the most affordable and convenient option. This can be supported by the provision of pedestrian and bicycle infrastructure allowing users of public transport to have safe, convenient and practical access to public transport systems (Advocacy Alliance 2014). Zhang et al (2015) also assert that all pedestrian improvements located within half a mile of public transport stops or key interchanges have a positive effect on public transport.

3.3.5 Public transport demand elasticities

Demand elasticity is the percentage change in patronage in response to a change in public transport service provision and is used to determine group behaviour. Currie and Loader (2009) suggest a typical short-run average elasticity to be 0.5 for improvement to service levels (spatial or temporal).

Demand elasticities tend to increase over time, and are affected by time of day, with off peak values being approximately double those of peak. This partly reflects the nature of trip purpose in each of these periods. Work and education trips tend to occur in the peak and have lower elasticity values than discretionary trips which tend to take place in off peak (Balcombe et al 2004). Currie and Loader (2009) report the measure of short-run patronage impacts in the range of 0.5 to 1.0 and long-run elasticities (over five years) being on average 50% greater when improving the quality of service provided on week day evenings and weekends.

This is relatively consistent with public transport demand elasticities stated by Balcombe (2004) which differentiate between demand with respect to changes in wait time (-0.5), walk access time (-0.6) and in-vehicle time (-0.4), and also Transfund NZ research report 248 (Wallis 2004). An example of how this can be applied, is to consider a service provision change that results in the walk access time increasing from 10 minutes to 12 minutes. The percentage change in patronage would be calculated as follows:

$$100[(12/10)^{-0.6}-1] = -10.36\% \qquad \text{(Equation 3.1)}$$

Increasing the walk access time by two minutes would likely result in a decrease in patronage of 10.36%.

Demand elasticities guide the likely magnitude of patronage change, but are not an exact science and will differ for different types of changes and different initial patronage values. Other aspects that need to be considered include:

- it is easier to lose passengers than it is to gain them
- journey purpose will vary the elasticity with optional trips having a higher elasticity than work journeys
- the time period over which the demand is measured

- elasticities are not necessarily transferable in time or space and are sensitive to income, car ownership rates and preference changes over time (Balcombe et al 2004).

An evaluation of a service change provision needs to consider the impact on patronage, and demand elasticities provide guidance to evaluate possible outcomes and likely impact on service value to be considered as part of the evaluation process.

3.3.6 Option value

Option value refers to the value that is placed on the availability of public transport to travellers that typically do not use public transport, but value the contingency of it should they be prevented from being able to use their preferred mode of choice for some reason. Including option value into the economic evaluation of public transport services is applicable in situations that involve the assessment of a substantially change in the availability of transport services (eg introduction of new public transport service, service abandonment or major service changes). Option value is likely to be considerable where public transport provides rural or isolated communities with access to a larger urban area, or in locations within urban areas with poor public transport access or service levels (Wallis and Wignall 2012).

Wallis and Wignall (2012) consider the assignment of option values in the New Zealand context through the use of market research willingness-to-pay telephone-based surveys to assign an option value per household. The option value is sensitive to the relative attractiveness of the available public transport service, the communities and urban centre it is connecting and the relative attractiveness of alternative car travel. Wallis and Wignall (2012) propose the inclusion of the default values shown in figure 3.4 into the *Economic evaluation manual* (EEM) NZ Transport Agency (2016b) for use in evaluating public transport service provision changes.

Figure 3.4 Proposed default values for inclusion in the EEM (source: Wallis and Wignall (2012)

Category	Notes on typical characteristics	Typical catchment area (km radius)	Default value (2010 $pa/ household)	Surveyed OVs within category (and additionality values)
High	• Good level of service (frequency, reliability, travel time, etc) • Car alternative relatively poor (congestion, difficult road conditions, etc) • Service well-matched to desired origins/destinations (stop locations, etc)	20–35km	$130	• Featherston – rail ($132) • Carterton – rail ($216)
Medium	• Between 'high' and 'low' characteristics[a]	10–25km	$75	• Tuakau – rail ($86) • Oxford – direct bus ($59)
Low	• Poor level of service (frequency, travel time, need to transfer, etc) • Car alternative relatively good • Service poorly matched to desired origins/destination (eg rail station away from town centre)	10–15km	$35	• Oxford – indirect bus ($40) • Te Kuiti – bus ($35) • Featherston – bus ($34) • Tuakau – bus feeder ($25) • Te Kuiti – rail ($25)

a) It is difficult to be more specific about the typical characteristics of the 'medium' category, beyond saying that they are substantially worse overall than the 'high' characteristics and substantially better overall than the 'low' characteristics.

ECONorthwest et al (2002) suggest an alternative methodology, applying the Black-Scholes call option pricing formula (equation 3.2) to evaluate public transport's option value.

$$C = SN(d_1) - Xe^{-rT}N(d_2) \qquad \text{(Equation 3.2)}$$

where

$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

The option value varies with the variation in the following key parameters:

S= the full marginal cost of a typical car commute trip

σ = the volatility or uncertainty of travel by car expressed as the standard deviation of the marginal cost of a typical commute trip

X = the full marginal cost of a public transport cost including the fare, travel time (in vehicle, walk to access and wait time) and other characteristics such as comfort and safety. This cost is generally expected to be higher than S

T= the expected number of times per year an optional user might use public transport

r = the risk-free return rate (eg 4%).

For example if the full marginal cost of a typical car commute trip is $5, the volatility $1.50, the full marginal cost of a public transport trip $6 and it is expected two public transport trips will be taken per year, the option value would be $1.78 per passenger trip (ECONorthwest et al 2002).

For public transport to have a high option value, it must provide a reasonable cost alternative to car travel, the volatility of vehicle costs must be high and the frequency with which the option will likely be executed be low (ECONorthwest et al 2002).

These methodologies are unlikely to be suitable to evaluate small changes in service provision as option value is likely to be insignificant given the changes are occurring in an urban setting with relatively good alternative public transport services available.

3.4 Public transport impacts

The economic and social aspects of a transportation system affect people in the wider community in addition to just those using the transportation system. Transportation system effects historically focus on how well the transportation system serves those directly using the system (Forkenbrock and Weisbrod 2001); however, many of the social and economic effects are intertwined. The economic evaluation of these effects typically involves quantifying and comparing the incremental benefits and costs of service provision (Litman 2015a). When assessing the value generated by a public transport network, it is important that economic benefits are not double-counted. For example, productivity gains from more accessible land use can be counted as land use benefits or economic benefits, but not both. The social effects of public transport are addressed later in this section.

3.4.1 Economic impacts

The EEM sets out the economic evaluation procedures to be used for calculating benefits and costs of land transport activities in New Zealand. These concepts will be addressed later in chapter 8 of the report. The focus on economic impacts in this section is generally pitched at a high level and considers the wider economic benefits of public transport.

Economic impacts include both direct and indirect effects. The main direct economic impact on a public transport network is the initial capital expenditure for infrastructure such as bus stop signage and furniture, clearways, Park and Ride facilities or bus bays. The operational expenses over the longer term include vehicle operating costs such as labour, fuel and maintenance. Direct impacts will result from increased mobility provided by public transport and reduced private vehicle use when people shift from driving to public transport. Indirect impacts result when a major public transport improvement becomes a catalyst for more accessible land use patterns and a more diverse transport system that leads to additional reductions in travel by private vehicles. These indirect effects can sometimes be known as the ‘leverage effect’. Analysis that only considers direct impacts and uses a short-term perspective tends to undervalue public transport investment (Litman 2015a).

Cervero et al (1998) acknowledge that what constitutes an economic impact can differ for a variety of reasons, whether due to the policy context of a particular study or the geographic area of interest, or may arise due to a practitioner’s misunderstanding of economic theory. The economic impacts of public transport investment were categorised as generative, redistributive and financial transfer, with several types of impacts within each category as summarised in table 3.2 below.

Table 3.2 Categories of transit- related economic impacts

Generative impacts	Redistributive Impacts	Financial transfer impacts
• User benefits (travel time savings, safety benefits, changes in operating costs) • Employment and income growth unrelated to system construction, operation or maintenance • Agglomeration / urbanisation benefits (eg high productivity, lower infrastructure costs) • External benefits (eg air quality) • Accessibility benefits (eg access to employment) • Reduced development cost due to reduced parking	• Land development (eg clustered development around transit stations) • Employment and income growth due to land development • Increased economic activity within corridor	• Employment and income growth related to system construction, operation or maintenance • Joint development income to local agencies • Property tax impacts

In smaller cities, public transport primarily serves the transport disadvantaged; however, as cities grow in size and density, public transport serves more discretionary riders (that is people who have the option of driving) and provides more benefits by reducing traffic problems and supporting more efficient land use patterns (Litman 2015a).

Investment in public transport contributes to the overall economic output at national and regional levels. However, a discrepancy exists regarding the magnitude and extent of these contributions. Some research has found increases in personal income of up to 0.2% for each additional 10% of public transport expenditure, while other studies have found much smaller or non-existent impacts (ECONorthwest et al 2002).

Hazledine et al (2013) found public transport can make a unique contribution to economic productivity in denser urban environments, concluding that public transport can create economies which increase regional productivity as a result of spatial concentration of economic activity. They found public transport can both encourage and enable increased employment in central city locations, by reducing commuting costs in congested transport networks and freeing up space that would otherwise be required for car parking.

Similarly, Litman (2015a) established that land use economies of agglomeration are leveraged by public transport, particularly high-quality rail systems that provide a catalyst for more compact, mixed, multi-modal community development.

The impact on productivity as a result of investment in public transport allows for the expansion of services and if sustained over time can affect the economy by providing (Weisbrod et al 2014):

- travel and vehicle ownership cost savings for public transport passengers and those switching from private vehicles, leading to shifts in consumer spending
- further direct travel cost savings for businesses and households as a consequence of reduced traffic congestion for those travelling by private vehicles
- improved reliability effects as a result of reduced congestion with ensuing business operating cost savings associated with worker wage
- business productivity gained from access to broader labour markets with more diverse skills, enabled by an expanded public transport service area and reduced traffic congestion
- further regional business growth through the indirect impacts of business growth on suppliers and induced impacts on spending of worker wages.

Efficient public transport systems will promote the integration of residential, employment and commercial centres which in turn can increase the ability of dispersed populations to generate wealth. An important role of public transport is facilitating productivity and opportunity by moving skills, labour and knowledge within and between markets. In a globalised world, labour, capital and enterprise seek out the most productive markets which encourages competition and mutual economic growth. The cycle of economic growth can be maintained through investment in public transport (Tourism & Transport Forum Australia 2010).

Economic benefits can also include direct spending effects such as capital investment in public transport, creation of jobs through the purchasing of vehicles and equipment, and the development of infrastructure and supporting facilities. Another direct spending effect is public transport operations including the management, operations and maintenance of the fleet and facilities (Weisbrod et al 2014). When assessing these effects, it needs to be considered that some impacts are economic transfers rather than net gains. For example, from a local perspective, government investment may be considered an economic gain, since the money originates from elsewhere. However, at a national level these are economic transfers and resources shifted from one area to another. Similarly, taxes and fares balance the costs to those who pay with benefits to those who receive the revenue. Both types of impacts should be considered in an economic evaluation framework (Litman 2015a).

A literature review by (Hazledine et al 2013) regarding the contribution of public infrastructure to gross domestic product (GDP), found that investment in public infrastructure contributes to increases in GDP. However, examination of aggregate-level studies does not indicate how this contribution has been made (direct or indirect) or specify how it was divided between particular types of infrastructure (eg transport vs communications, or road vs rail).

3.4.2 Direct user, social and health impacts

Investment in public transport is likely to be key for a sustainable future in large metropolitan areas with growing populations. Core to the planning and provision of public transport are the fundamentals of a network that delivers frequency, connectivity and visibility that provides value for money in terms of net social benefit per dollar outlaid (Hensher 2008).

Public transport can deliver mobility benefits by providing a transport option to the 'transport disadvantaged'. Byrd et al (1999) examined how public transport can reduce the effects of personal immobility for the transport disadvantaged. They found transportation practices that successfully addressed immobility, particularly for better access to health care and to jobs, clearly provided economic and societal benefits.

The mobility benefits enabled by public transport can be classified as user benefits, equity benefits, public service support and option value (Litman 2015a). Direct users of public transport benefit from increased access to services, social and recreational activities. It can improve access for people to education and jobs which in turn can improve people's economic opportunities. By providing these people with better access to public services, education and employment prospects, public transport helps to achieve community equity and reduce the degree to which non-drivers are disadvantaged compared to motorists (Litman 2015a).

There is also the 'option value' of public transport, which can be regarded as a secondary benefit. The option value is the value people place on having a transport option available even if they do not currently use it or plan to use it regularly. ECONorthwest et al (2002) examined the option value of public transport and found while public transport is not unique in offering expanded travel options, it can offer more of an option for most travellers compared to providing additional road capacity.

The potential health benefits of public transport are primarily realised through the access provided to healthcare resources and services (Christl et al 2009). As noted by Litman (2015a) and ECONorthwest et al (2002), public transport can also support government agency activities and reduce their costs by providing low-cost mobility options. There are a number of aspects to this, first, those who are transport disadvantaged may be unable to reach medical services which may result in more acute and expensive medical problems. Second, public transport provides a low-cost mobility option which can reduce the need for government agencies to pay for a taxi or avoid a more expensive house call. Last, public transport can influence the extent to which elderly or disabled people live independent lives.

There can also be significant health benefits from the way people's personal travel activity is affected by high-quality public transport developments. This can include increased physical fitness, improved mental health and increased affordability which reduces financial stress to lower income households (Litman 2010). Increased physical activity appears to be linked to active transport modes, of which public transport is one (Christl et al 2009). Physical activity generally increases among public transport users as most public transport trips include walking or cycling which has ensuing health-related benefits. These health benefits tend to be less tangible as they are difficult to measure and as a result can often be undervalued. Sedentary lifestyles can be a substantial health risk, therefore increasing the physical activity of otherwise sedentary people through increased public transport use and development may provide significant health benefits (Litman 2015a).

The benefits of public transport resulting from reduced traffic crashes are noted by Litman (2010) and ECONorthwest et al (2002), although public transport projects are unlikely to be undertaken with a main objective of reducing or mitigating traffic hazards. Other safety-related benefits which may result from improvements in public transport services are a reduction in insurance costs, personal losses and emergency response costs as a result of fewer collisions occurring. Weisbrod et al (2014) categorise these benefits as follows:

- crash reductions for those shifting from private vehicles to public transport due to the significantly lower crash rates for public transport
- crash reductions for those still travelling by private vehicle due to a reduction in congestion and hence congestion-related collisions
- crash reductions to the extent that as there are fewer cars on the road in the long term, pedestrian and bicycle crashes and fatalities involving vehicles will be reduced
- reduced costs of traffic enforcement and emergency services.

The contribution of public transport to inclusive communities was explored by Allen (2008) who found the ability to access jobs, education, health services and other facilities is a key factor of social inclusion. Allen (2008) found there are a number of ways in which restricted mobility and limited access to transport, whether because of cost or availability, can increase social exclusion by:

- limiting the possibility of flexible working and reconciling work and family life because of the difficulty of moving easily between home and work
- restricting the opportunities for immigrants and ethnic minorities living in disadvantaged areas to engage in and integrate with the wider society
- limiting the possibility or economic and social regeneration of disadvantaged communities.

In their report assessing the social and economic effects of transportation projects, Forkenbrock and Weisbrod (2001) discuss the effects on 'community cohesion' which need to be taken into account when there are any changes to the transportation system. Community cohesion is described as 'the patterns of social networking within a community'. The benefits of community cohesion are less tangible given that it is quite difficult to assign a monetary value (Goavarthy et al 2014). Public transport can play an important role in this community cohesion by contributing to an improved sense of social inclusion for low-income and outer-urban households as well as for individuals who have mobility problems due to age or disability. By providing people with a means to travel to work, education, health care, or to participate in a variety of social and recreational activities, this can positively influence the health of populations (Christl et al 2009).

Those who are transportation disadvantaged can be seriously affected by even small changes in transportation systems, for example low-income non-drivers may be highly dependent on a particular public transport route because their transport options are constrained (Forkenbrock and Weisbrod 2001). Mees et al (2010) found the successful restructuring of a public transport network requires extensive community involvement at all stages of the process. They found users are more likely to accept additional transfers where there are clear benefits gained in terms of speed and frequency and it may be easier to introduce change through substantial network overhauls rather than through piecemeal changes to individual routes or lines. This is particularly relevant when addressing the relevance of lower patronage feeder services which facilitate the ability of passengers to transfer from a low-frequency service to a high-frequency service.

3.4.3 Environmental impacts

Environmental impacts can be classified as secondary impacts given that they are derived from the primary impact of building, operating and maintaining public transport facilities and services. An effective public transport system can result in reduced air pollution, water pollution and noise through the reductions in private vehicle use (ECONorthwest et al 2002).

Environmental impacts are sensitive to travel conditions and the types of public transport vehicles used. Load factors on public transport have a significant impact, as during peak periods, when load factors are high, buses are the most energy efficient mode, but during off-peak, when load factors are low, buses are least efficient. Increasing patronage on existing vehicles consumes little additional energy. Litman (2015a) cites a General Motors study that states a bus with seven passengers is about twice as energy efficient as an average private car, and a bus with 50 passengers is about 10 times as energy efficient. Rail transport systems tend to be about three times as energy efficient as diesel bus transport. New hybrid buses are about twice as energy efficient as current direct drive diesel. In Australia the potential for public transport to play an integral role in the reduction of transport-related carbon emissions has been recognised and the use of electrified modes such as rail and light rail will play a particularly important role. As more renewable energy sources become available these modes have the potential to become completely sustainable (Tourism & Transport Forum Australia 2010).

Public transport initiatives must be effective in advancing a mode shift from the private vehicle if they are to have measurable environmental benefits. Strategies that:

- increase diesel bus mileage on routes with low load factors (such as suburban and off-peak routes) may increase total energy consumption and emissions
- shift travel from automobile to public transport using existing public transport capacity (with minimal increase in public transport vehicle-miles) reduce energy consumption and emissions
- improve fuel consumption or reduce emission rates of public transport vehicles (for example, retrofitting older diesel buses with cleaner engines or alternative fuels) can provide energy conservation and emission reduction benefits
- reduce the total amount of congested driving (by either reducing vehicle mileage or the amount of congestion) tend to provide particularly large energy conservation and emission reduction benefits
- create more accessible land use patterns, and so reduce per capita vehicle mileage, can provide large energy conservation and emission reduction benefits (Litman 2015a).

3.5 Land use and property value effects

One important aspect of valuing a public transport network is understanding the relationship between public transport and land use. The development of public transport is crucial in the planning and implementation of a transportation network and will improve land use and transport operational efficiency. The main land use factors affecting public transport use are density, diversity and design (Lee et al 2013). Transportation infrastructure increases the supply of land with potential for development and through the competitive bidding process increases the price of land for parcels that enjoy significant gains in accessibility. The benefits of new transportation investment become capitalised in real estate prices in the short term while over the longer term land use adjustments can occur. While land-price impacts can be immediate, land use changes tend to be slower and are sensitive to policy, zoning and development requirements (Cervero and Kang 2011).

The basic concept underpinning the relationship between land use and transportation is accessibility. Increased access to jobs and urban services results in less cost in terms of money, time and transportation. Public transport accessibility can be measured by the reach enabled by the public transport system from a specific location. Public transport can improve the accessibility of properties, reducing both travel time and costs and generally translates into higher property values provided the accessibility effects prevail over the negative proximity effects (Rosiers et al 2010). Cervero and Kang (2011) also point out it is not the buses, trains and ferries themselves that achieve land use changes, but rather the quality of service and travel time savings compared with the private car.

Over the long term, a public transport system will often have an overall positive and visible impact on property values that are close to key transport nodes and situated on transport corridors (Litman 2015b). Consideration needs to be given to whether the increase in the value of a property is due to its close proximity to public transport and therefore capitalises on access cost and travel time savings associated with those locations, or other neighbourhood characteristics. In undertaking an economic evaluation, careful consideration needs to be given to whether a value has been placed on accessibility through value-of-time savings and ensure that double counting does not occur (Weisbrod et al 2014).

Public transport systems have the potential to impact on development by changing the relative accessibility. An increase in property values in the vicinity of a new public transport corridor may be offset by reductions elsewhere (Damm et al 1980). Handy (2005) agrees that an increase in property prices associated with an increase in accessibility from transport results in a shift in development from one location to another in what is called a redistributive impact.

3.6 Similar research

US-based consultant Keith Hall undertook a review of international literature specifically for this research to establish an understanding of current international research approaches related to public transport network planning evaluations, and whether there were any existing methodologies for valuing the range of elements that contribute to the overall value of a public transport network. The review focused on attempting to find any case studies that had already been successful in addressing the research question either partially or in full. Case studies and the research team's comments arising from the review of similar research is detailed in appendix A.

It appears that industry-oriented research is focused on practitioners where a fundamental assumption is made that feeder networks exist and serve to extend coverage and access, in doing so contributing toward the success of trunk lines. The literature, however, focuses on maximising the effectiveness of feeder services, not evaluating their benefit to the network as a whole.

The academic research is highly focused on testing mathematical models developed to achieve maximum efficiency based on the underlying assumption that networks seek to achieve a balance between access (value to users), network travel time (measured by cumulative user travel time), and fleet utilisation and operating resources.

This review established that no existing literature was able to provide examples of determining the value or utility of feeder networks in isolation of the overall network effect including addressing social impacts. Some of the case studies acknowledge the trade-off between social and access considerations and cost/revenue considerations, but do not provide specific guidance as to how these trade-offs can be addressed.

4 Stakeholder consultation

The research team contacted 25 key stakeholders to collect their views on a range of issues relating to the value of public transport as a network, the network effect, and the value added to the network by services that in isolation may be inefficient.

4.1 Methodology

The broad purpose of the stakeholder consultation was to:

- understand how stakeholders value public transport
- understand what components and considerations are critical to decision making
- understand what data and information are available to support the latter technical analysis stages of the research
- learn from stakeholder experiences in network planning, especially with regard to:
  - considering expanding spatial and temporal coverage
  - feeder services
  - accessibility constraints
- understand connections between policy expectations and delivering value-based networks.

Stakeholder interviews were undertaken with the Transport Agency national and regional representatives, Auckland Transport, Greater Wellington Regional Council, Environment Canterbury, Northland Regional Council and Waikato Regional Council. The response rate of stakeholders approached by the research team was 80% and a number of referrals were made to include other stakeholder representatives, demonstrating a healthy level of interest and engagement in this research topic.

The majority of stakeholder interviews were carried out in person in Auckland, Wellington and Christchurch with two members of the research team present. Additional telephone interviews were conducted with participants outside these main centres or where face-to-face interviews were not able to be scheduled. The participants were invited to be interviewed either individually or in groups, and consultation sessions lasted between 30 minutes and one hour depending on the number of participants involved. At each session, both research team members recorded notes on key points and themes which were compared and collated with all other responses for reporting purposes.

It is important to note multiple interviews were held with some stakeholder organisations to receive a cross section of views across the breadth of the organisation. In some instances, not all of the questions were raised with each stakeholder interviewee depending on the areas of knowledge and expertise of the interviewee.

This chapter of the research report summarises the outcomes and learnings arising from these interviews. The responses from stakeholders have largely been anonymised and aggregated, although specific examples have been used on occasion to illustrate a particular point or highlight differences between regions.

4.2 Components critical to network planning

In order to get an understanding of the main drivers of network planning decisions, stakeholders were asked what the key factors were that influence a decision to change the network. Four key factors emerged as described in the following sections.

4.2.1 Regulatory environment and funding environment

New Zealand regional councils have either recently or are currently undergoing network reviews in order to meet updated central government requirements, in particular the new Public Transport Operating Model (PTOM). PTOM aims to align planning, procurement and business development decisions and as part of PTOM's implementation councils were required (if they were not planning to do so already) to review their existing services to determine they were still fit for purpose, as well as organise services into units as required under the Land Transport Management Act 2003.

Regional public transport plans (RPTPs) set the framework for the planning and operation of public transport. They need to be outcome focused and show value for money. Procurement strategies are developed in parallel with RPTPs including details of contract components and transition plans relating to public transport services and infrastructure. Some stakeholders considered the guidelines provided a generous outline and framework for regional councils to work with and optimise their networks but acknowledged uncertainty to whether the regulatory environment allowed for sufficient customisation and flexibility to address the variety of demands on public transport. Stakeholders also expressed frustration regarding the relationship between regional councils and local roading authorities due to different and often conflicting priorities.

An alternative approach to determining value suggested by one stakeholder could be to assess a project's contribution value over the five well-beings of safety, social, cost, network capability and capacity and environmental without isolating any one aspect.

The final key theme to emerge was a perceived difference between some organisations' policy direction and expectations, and their business practices and risk management culture. Policy areas where this was identified included the Transport Agency's 'one network' approach, RLTPs and alignment with the business case approach. Stakeholders were acutely aware of their respective organisation's expectations and policy direction in these areas; however, many felt the culture and bureaucracy of their organisation together with public expectations challenged network design principles, the promotion of 'innovative' solutions and professional judgement in the provision of the most efficient value-based networks.

4.2.2 Cost efficiency

Overwhelmingly, stakeholders rely on patronage and corresponding revenue measures as key drivers to influence network decision making and evaluating network deficiencies. From a national perspective there is a drive to increase patronage and the commerciality of public transport routes to achieve value for money for investment.

The assessment at this level uses a holistic view to valuing networks as a whole rather than looking at key indicators for services in isolation. At a regional operational level, patronage provides a gauge to monitor issues of poor utilisation or over-capacity/demanded services which are often the catalyst for network reviews. Capital constraints also influence decision making. Urban networks experiencing capacity constraints face pressure to remove buses from low patronage under-performing routes and reallocate them to over-patronised corridors.

In assessing the value of a network it is important to consider other external factors that influence patronage and corresponding revenue associated with services. One stakeholder had noted a cause-and-effect relationship between fuel prices and patronage numbers whereby a drop in fuel price coincided with a decrease in public transport patronage.

Funding was also noted by the majority of stakeholders as a fundamental aspect of decision making. In a funding-constrained environment, network reviews largely aim to minimise cost, or be cost neutral and achieve increased cost and network efficiencies. Balancing the attractiveness of the network with cost efficiency goals was stated as a challenge by stakeholders. Removing the long suburban 'wiggling' associated with the first mile and last mile from a route facilitates the creation of straighter, higher-frequency routes that are more attractive and reliable. New feeder routes are then established to provide coverage for suburban areas; however, these routes may be more vulnerable to high service costs that restrict the commerciality of the individual unit.

Stakeholders conveyed frustration regarding a disconnect between practical operational possibilities and public expectations. Limited funds create demand to provide for over-subscribed routes in preference to providing a social service for areas with low public transport uptake, yet as a portion of public transport provision is funded through general rates, the public convey a sense of entitlement to have their share of rates used to meet their needs. Additionally, there is a desire to be innovative and proactive with planning networks applying the notion of 'build it and they will come'; however, this is constrained by patronage, lack of buses, past network performance and funding. Some organisations also acknowledged that funding and a drive for cost savings created capacity constraints to engage with people in some areas. A 'hearts and mind' approach was often used in the absence of the ability to quantify benefits.

A common observation among stakeholders was that too much emphasis was placed on farebox recovery which is considered to be 'a very blunt instrument'. Farebox recovery fails to capture all components of value attributed to a service and is generally less suitable for assessing smaller regions' networks or individual units. For example, while integrated fares help lift the attractiveness of feeder services to the consumer, the distribution of the fare over multiple services reduces the fare box recovery of the feeder service. Some stakeholders expressed a view that feeder services provide a pragmatic alternative to the provision of free park-and-ride facilities and in doing so free up the park-and-ride site for other purposes.

While discussing the elements that contribute to the value of public transport, the optimisation of capital and fleet investment was raised. A number of stakeholders identified there was a crucial balancing act between the drive for value for money and the desire for improved technologies including fleet renewal and a transition to environmentally friendly vehicles. The emerging options for high-capacity vehicles and their role in terms of benefits in reducing emissions and congestion is largely unmeasured or not considered in the public transport value proposition. There was also recognition that while a service or network can be flexible, fleet investment and vehicle specifications are locked in for significantly longer periods.

4.2.3 Congestion relief

To achieve national economic growth and productivity goals, the national policy directive is to prioritise transport initiatives that ease congestion and improve journey time reliability (MoT 2015). For regions with large metropolitan centres, congestion relief was considered part of network planning decision making in order to access funding through the National Land Transport Fund (NLTF) and to reduce road-related costs and improve journey time reliability.

Smaller regions felt they have little or no congestion so do not meet central government measures to access funding. However, public transport in these areas potentially had a greater social function and could be considered in funding decisions in areas where congestion was not a problem.

4.2.4 Community feedback

Community engagement is a fundamental input to the public transport planning process; however, one of the biggest challenges faced by regional council network planners is responding to individual public transport needs and managing the sense of entitlement of the public. Accommodating all requests would lead to an inefficient network, so a careful balance is required. Another contentious issue is considering network or route changes requiring transfers between services which are generally perceived by public transport users as inconvenient and a potential deterrent.

Public support of routes and the development of routes that meet the needs of the community is vitally important to support investment in services. Some councils cited the operation of new or extended routes and services on a trial basis. This provided an incentive to the public to 'use it or lose it', and this was always well communicated to the community and stakeholders conveyed this worked well.

4.3 Valuing social elements

Stakeholders were acutely aware of their organisation's expectations and policy direction in addressing social needs; however, many felt that the drive for commerciality, culture and bureaucracy of their organisation stood in the way of fully measuring the social value and enabling effect of marginal services or the need for service provision. This was more evident in the larger urban settings, whereas in regions with large areas of social deprivation and/or a wide spread populace, the social value of services is much greater and in some instances collaboration between the community and private sector has enabled innovative solutions to be achieved.

Northland Regional Council (NRC) has examples of successful community driven point-to-point services (with schedules to meet community needs) that originated to purely address access and social needs of sectors of the community, including the elderly and isolated communities. NRC engaged with the community to provide a purpose driven service several days a week, to keep service costs to a minimum and use informal agreements with businesses, schools, hospitals and small freight companies as well as targeted rates to provide additional resource. Services like these will generally struggle to meet current NLTF criteria under the existing framework due to low financial efficiency and a lack of recognition of the social value of the services. However, after a successful initial trial the NLTF has supported the continuation of these services.

Waikato Regional Council provides examples of recognising social need and enabling services to meet these needs. In the first example, the community and the council identified core issues and possible solutions acknowledging a proposed new service would be very unlikely to stack up under national funding guidelines. Rather than investing in the compilation of the business case, Waikato Regional Council provided funding for a trial service that met the high social needs of the community. A second relevant example is a project that was looking to reduce barriers for individuals to access university education. The University of Waikato funded a bus service to facilitate transport to a sector of the community which previously did not have access and it is understood this contributed to an additional 50 enrolments in the university.

Stakeholders identified the need to value the social aspect of public transport, and it was acknowledged the complexity of quantifying it would present a real challenge. In high areas of deprivation public transport facilitates access to jobs, health care and education. The cost of not having access perpetuates the cycle of deprivation and exacerbates the need for additional social and healthcare services.

Some stakeholders raised the question of what the definition of a public transport network is, and where does transport investment start and stop. Current central government funding for public transport comes from the road user through the NLTF. Some stakeholders found it challenging to determine whether it was appropriate to use road user funding to invest in low value rural areas or areas of high social need, acknowledging that social needs may have to be funded from outside the transport sector.

4.4 Public transport planning and investment challenges

4.4.1 Meeting current and future needs

In order to get the best value out of public transport networks stakeholders thought consideration needs to be given to what a 'fit for purpose' public transport network looks like, and whether there is a need for more customisation or flexibility within the network. The challenge of meeting current and future public transport needs and establishing a fit for purpose network makes getting the first and last mile right critical to maximising the value of public transport. Satellite communities and green field growth areas become part of the first and last mile issues unless opportunities are explored to be forward thinking and understand where people are travelling to and what their transport needs are.

Several stakeholders believed that one of the biggest challenges is to move away from the current reactive, retro-fitting approach to public transport planning. A number of stakeholders thought in general New Zealand does not plan for public transport effectively, opting to retrofit existing networks which compromises good urban form and creates networks that are unattractive to the large majority. It was suggested greater emphasis should be placed on understanding emerging social and transport trends and future proofing networks by focusing on how well the network or service will suit the future needs of the community. Some regions have ventured with this in their current review, adopting a philosophy of 'build good public transport and the people will come'. The use of demand responsive and shared passenger transport models were two considerations raised in the public transport space as the popularity of choosing not to own a car increases.

It was acknowledged customers require access to transport systems that reflect our emerging transport needs, car ownership rates and lifestyle choices. Several stakeholders raised concerns as to whether current network planning considers these future needs as there appears to be uncertainty in this regard, particularly for the smaller regions. Providing networks that meet current and future needs is likely to highly correlate with the current and future value of a network.

4.4.2 Political influence to decision making

The challenge of justifying public transport planning decisions to politicians was raised by a number of stakeholders. Inference was made to the often difficult circumstances of engaging with community boards and politicians wherein it was perceived that sometimes decisions were made to keep the peace and cause as little contention as possible. Some stakeholders also expressed concerns that public transport decisions were often skewed by political agendas, image protecting, a risk adverse culture and other goals for the community.

Stakeholders thought it would be valuable to have a mechanism or evidence to measure the value of services that experience low patronage as decision makers often have a perception that largely empty buses are highly inefficient.

4.4.3 Conflict with other modal decisions

A further challenge arising from the stakeholder interviews was to identify and approach transport problems with a greater focus on the most effective solution for all modes. Using the multi-modal integrated 'one network' approach to planning for transport solutions from the outset is likely to yield greater benefits than assessing individual modal responses and needs in isolation.

A few stakeholders noted the conflict between investing in public transport and easy investment solutions for cars and cheap parking options, with one participant considering these measures often 'cannibalise' public transport. A recurring theme was the need to focus on providing better information on how people can move effectively around public transport networks to avoid using private vehicles. Generally, stakeholders thought providing better traveller information together with investing in measures that lift the image of public transport, public transport users and the look and feel of public transport interchanges would be useful to increase the appeal of public transport to a wide sector of the population.

4.4.4 Accessibility constraints

Stakeholders were asked what indicators they used to measure the accessibility, coverage and connectivity of a network. In general, these metrics are governed by statements in planning documents such as the RPTPs for coverage and accessibility and are measured through the requirement to have a target percentage of the population within a specified distance (often in the range of 400m to 500m) of a bus stop or frequent bus route. Access to key activity centres was also a measure used to develop or expand a route.

Public consultation feedback helps stakeholders to understand accessibility, coverage and connectivity from the customer's perspective. A general reluctance to transfer between services is understood to limit the public's perceptions of public transport coverage. Negative feedback received by councils would suggest that transfers and poor connectivity between modes can create a barrier to people's willingness to use public transport. This is particularly evident when timetabled connections are not going to the places wanted or are not in place at all, or if the facilities at stops were not sufficient for the required wait time. There was also a sense of frustration when the infrastructure needs did not match the network requirements.

Stakeholders highlighted the importance of growing connectivity and improving the integration and connectivity of footpaths to bus stops as a key measure to improve access. These measures were considered to provide a cheaper mechanism in terms of infrastructure requirements than the addition of point-to-point service growth that required park-and-ride facilities and high peak bus requirements.

This ethos conflicts with the public's general resistance to transfer between services and take feeder services for small distances to connect to high frequency services. A customer's decision to use a feeder service was often made based on the value of the wait time as a portion of the feeder service length and total journey length.

A number of stakeholders were asked to suggest possible alternative indicators for valuing access. Several stakeholders suggested using Total Mobility data to compare the cost of a bus/train trip with that of a Total Mobility trip in relation to income. An alternative accessibility indicator was proposed to measure income level as a proportion of transport spend.

4.5 Data and information requirements

Stakeholders were asked to identify specific data and information resources they were aware of that could be used to value public transport network components and their contribution to the network as a whole, and what they perceived the critical information gaps to be.

The stakeholders identified the lack of high-quality, reliable data as one of the most critical information gaps for network operational and investment decision making. There is currently no integrated approach to data collection or network metrics. Regional councils manage the collection and analyses of network performance indicators individually to meet the requirements of local and national policy guidelines. The accuracy and breadth of information gathered appears to vary between regions; however, in general terms the data is imprecise, highly aggregated and interviewees had little or no access to mapping tools. It is understood the Transport Agency is working towards a more integrated approach to increase the consistency and accuracy of information available and supplied to them.

A summary of the breadth of information both available and missing identified by stakeholders is presented in table 4.1.

Table 4.1 Available data and key data gaps identified

Available data	Data gaps
Patronage (boardings by mode)	Capacity/occupancy of services
In service kilometres	Customer satisfaction/quality of travel
Origin/destination survey (every 2–3 years)	Where people get on and off the service for networks without tag on/off systems
Farebox recovery	Origin/destination 'journey' information
Total passenger kilometres	Trip lengths (distance and time)
Fleet size	Number and location of transfers
Customer survey results	Travel time variability and reliability
Cost of service provision	Accessibility to the network indicator
Cost per boarding and passenger km travelled	Patronage trend analysis over time
Total Mobility data	Measure of social benefit and enabling effect
SuperGold card usage	Economic value of social inclusion
	Option value or transport choice
	Level of service indicator
	Network attractiveness

5 Network value assessment approach

5.1 Background

The research sought to understand and appraise the additional incremental value added to a public transport network by services that in isolation might be comparatively inefficient. The stakeholder feedback highlights the importance of developing an appraisal approach that is not limited to assessing tangible economic value based on revenue and cost aspects of public transport provision, but acknowledges and assesses social and other impacts of a public transport service also.

The literature review and stakeholder engagement stages of the research provided insight into the value components that may be linked to temporal, spatial and other operational changes in public transport service provision. However, a review of the relevant research publications and journal articles found no specific studies that prescribe a methodology for deriving a value for a network that would be directly transferrable to this research. The components that impact on the value of a public transport network identified in the literature review and stakeholder consultation stages are summarised in table 5.1.

Table 5.1 Elements that impact on the value of public transport

Impact	Benefit/disbenefit	Stakeholder consultation	Literature review
Cost	Change in development cost due to parking supply/demand		✓
	Traffic enforcement variation resulting from change in traffic volume		✓
Land use	Relationship with property value		✓
	Land use accessibility/integration		✓
	Accessibility, connectivity and coverage of transport network	✓	
User/social	Travel and vehicle ownership cost savings		✓
	Social inclusion – accessibility to jobs, education and other facilities	✓	✓
	Community cohesion		✓
Health	Access to healthcare		✓
Mobility	Low cost, affordable transport option		✓
Environmental	Pollution (air, noise) through change in private vehicle use		✓
	Energy efficiency or resource cost Change in per capita vehicle mileage		✓
Road safety	Improve general road safety through reduced traffic crashes		✓
	Crash reduction through congestion relief	✓	✓
Mode shift	Patronage change		✓

The research team developed an assessment approach comprising four stages:

- data collection
- spatial and temporal analysis
- economic analysis
- accessibility and social/demographic evaluation.

Two case study areas (Auckland and Waikato) are introduced to demonstrate the concepts being developed in the assessment approach. These illustrate how an assessment of the value of a service can be developed to inform decision makers prior to the removal or reduction of service provision. A more holistic approach has been taken to some of the less tangible impacts where the magnitude of the impact would be location sensitive and likely require further data input.

A schematic plan of the assessment stages, datasets and workflow is shown in figure 5.1 and is discussed in greater detail in chapters 6 to 9.

5.1.1 Data collection (chapter 6)

The research team sourced data sets that showed promise to form the basis of valuing public transport service provision following stakeholder feedback. A high-level assessment of the data collected emphasised the rich nature of the integrated ticketing data from which the basis of a methodology for valuing a component of the network could be explored and developed. The ticketing data was integral to understanding patronage numbers, trip length and gather a general understanding of travel behaviour spatially and temporally. Census data was then collected to gather a greater understanding of the social aspects of households and the value they may place on access to public transport.

5.1.2 Spatial and temporal analysis (chapter 7)

The spatial analysis focused on analysing the data sets to determine how individual network elements could be valued, and their contribution to the network as a whole measured. This is demonstrated through the introduction of two case studies. First, a spatial proof of concept was developed by isolating the last few kilometres of an existing service in a suitable area of the network based on Auckland HOP card user ID usage. Specialist geographic information system (GIS) software allowed the electronic ticketing transaction data, General Transit Feed Specification (GTFS) data feeds, demographic and property data to be spatially mapped and statistical analysis undertaken to identify user travel behaviour and trends. This allowed evaluation of the change in access to the public transport network, and of the impact of enabled trips on network value following a change in spatial coverage. Second, a temporal proof of concept was considered. The temporal analysis followed a similar process, exploring the extent to which these data sets could be used to measure the value of a network component (evening services) through isolating the users of evening trips on the length of one full service rather than focusing on a geographical area.

5.1.3 Economic analysis (chapter 8)

Following the development of spatial and temporal proof of concepts from the data sets, economic analysis was undertaken to enumerate the benefits and costs of changes in public transport service provision. The EEM procedures were applied and modified to achieve this.

The EEM is the industry's standard for the economic evaluation of land transport activities in New Zealand. The EEM sets out economic evaluation procedures and values used in calculating benefits and costs, necessary for completing a benefit–cost appraisal. The benefit–cost appraisal is used to determine the economic efficiency of an activity seeking funding from the Transport Agency. Using the data outputs from the spatial and temporal analysis, a methodology for measuring and understanding the value of a public transport service (spatial and temporal) coverage was developed through the application and modifications of the EEM simplified procedures. The methodology recognises the additional value to the network of trips that are enabled as a consequence of a service and also provides guidance on adjusting the EEM procedures to reflect observed trip lengths rather than the default trip length values.

5.1.4 Accessibility and social/demographic evaluation (chapter 9)

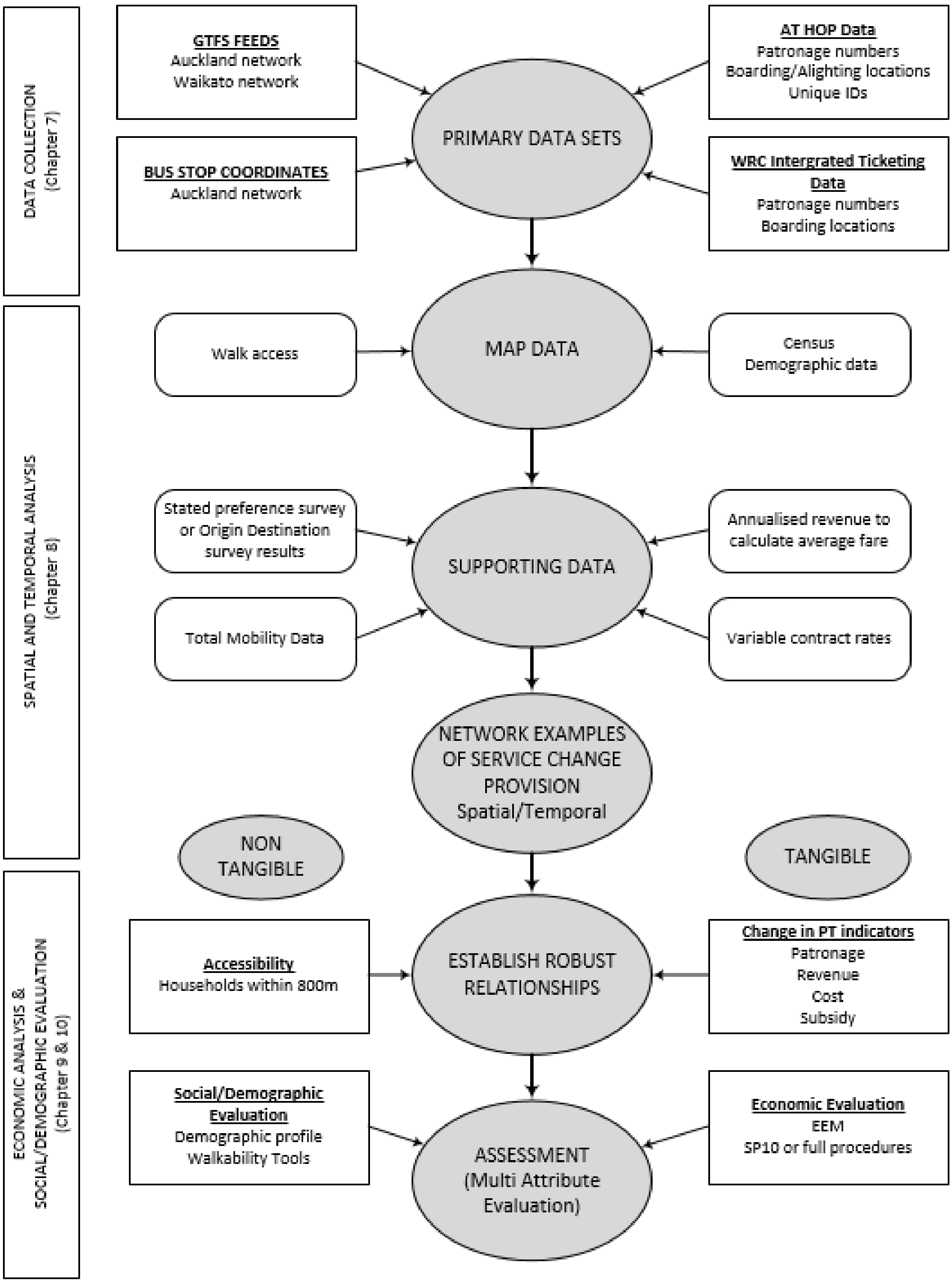
In addition to the economic assessment of a change in public transport service or coverage, the research sought to provide a mechanism for assessing and recognising other factors that contribute to the value of public transport. It is important to consider how some of the less tangible elements can be assessed and how their contribution to an individual service and the network as a whole can be measured and incorporated into network planning decisions. An assessment using a LoS type approach to measure the social and accessibility impacts of a change in service provision on the community it services is presented.

5.1.5 Case studies and application

Two case studies are presented in chapters 6 to 9 to demonstrate the application and modification of the EEM simplified procedures and social/demographic assessment.

The proof of concept developed provides guidance, and using the case studies as examples, demonstrates a method by which practitioners determine the value of a service and the additional value it adds to the network and the community it services. The Auckland case study provides an example that is expandable and readily applicable to other locations with fully integrated ticketing systems. The Waikato case study is representative of most other New Zealand regional centres, with more limited or no integrated ticketing data sets.

Figure 5.1 Data collection, analysis and assessment framework



6 Data collection

6.1 Introduction

During the stakeholder engagement, information was collected from regional councils regarding the availability of data which might be useful to value public transport network components and their contribution to the value of the network as a whole. The research team and steering group agreed Auckland and Waikato were suitable case studies and a formal request was made to the corresponding councils to supply raw data from a number of sources, which was used as the foundation for assessing the value of a public transport network.

The key data resources that inform the subsequent stages of this research are discussed in the following subsections.

6.2 Primary data

6.2.1 Patronage data

Electronic ticketing data is the primary data set required for the spatial modelling and analysis. While each region operates different systems, the key attributes requested were:

- unique trip #
- route ID#
- passenger card ID#
- boardings (time and day)
- origin/destination
- bus stop ID
- bus stop coordinates
- fare type.

Comprehensive passenger movement data was received from Auckland Transport and Waikato Regional Council. The research team sensibility checked all data received and cleaned the data to remove any outlying or erroneous data. Data and outputs were extensively checked to ensure the accuracy of key statistics were robust.

Auckland Transport supplied integrated fares system (HOP) data for all transactions on their network on three 'typical' days. A typical day was determined as a Wednesday in school term time. This provided a source of start-to-end public transport movement data from which patronage numbers could be extracted and journeys evaluated. The unique card ID# field allowed the research team to anonymously identify individual public transport users within the data set. This enabled total trips to be analysed, transfer between services and modes to be examined and new users to be identified.

Waikato Regional Council operates a tag-on only electronic ticketing system on their bus fleet recording boarding locations only. One 'typical' day of ticketing data by route and by stop was supplied; however, unique card IDs or transfer matrices were not available. Similar to the AT HOP data, the Waikato BUSIT data records enabled an evaluation of public transport demand by route, stop, meshblock area and time of day to be undertaken.

In the absence of transfer matrices, Waikato Regional Council supplied the most recently available origin–destination survey data (collected in 2013) which contained transfer information, trip purpose and additional information by route. This was used to understand trip distance and transfer behaviour of users on the Waikato bus network, and the research team acknowledge that the age of this data was a limitation in the subsequent analysis.

The Auckland integrated ticketing data provided the best-case study from which to base and test the proof-of-concept development, and to explore the impacts of spatial and temporal changes to the network. The limitations of the Waikato data, including no tag-off, no user unique IDs or geo-referencing meant a more simplistic and indicative approach needed to be taken to the spatial modelling and analysis for this case study.

6.2.2 Service information

General transit feed specification (GTFS) is the common format that describes a public transport system scheduled operations and associated geographic information. Current and historic Auckland and Waikato service information was sourced from publicly available GTFS data feeds and mapped by GIS specialists. Online route information available on each of Auckland Transport and Waikato Regional Council's websites also provided useful guidance and information.

6.3 Secondary data

6.3.1 Demographic data

Statistics New Zealand census data provides a source for understanding the demographic profile of households in the area of evaluation, and baseline social drivers that may influence public transport demand in this area. The New Zealand 2013 Census data was interrogated and the following fields extracted (at a meshblock level) and mapped for the study area to inform the research analysis:

- usual resident population by age (<5 years, 5–19 years, 20–64 years, 65+, total)
- number of people per dwelling
- number of households
- household income
- number of motor vehicles
- deprivation index.

The New Zealand Census uses the NZDep2013 scale of deprivation from 1 to 10. A score of 10 indicates the meshblock is in the most deprived 10% of areas in New Zealand (Atkinson et al 2014). The deprivation scores are based on nine different dimensions as outlined in table 6.1.

Table 6.1 Deprivation score dimensions (source: NZDep2013 Index of Deprivation)

Dimension of deprivation	Description of variable (in order of decreasing weight in the index)
Communication	People aged <65 with no access to the internet at home
Income	People aged 18–64 receiving a means tested benefit
Income	People living in equivalised[2] households with income below an income threshold
Employment	People aged 18–64 receiving unemployed
Qualifications	People aged 18–64 without any qualifications
Owned home	People not living in own home
Support	People aged <65 living in a single parent family
Living Space	People living in equivalised households below a bedroom occupancy threshold
Transport	People with no access to a car

It is noted that school decile weightings may be another useful indicator of deprivation to consider social needs in the vicinity of a school. The Ministry of Education uses census data for the community where the school's students live, to calculate school decile ratings. Deciles are based on five socio-economic indicators:

- percentage of households with income in the lowest 20% nationally
- percentage of parents receiving income support benefits
- percentage of employed parents in the lowest skill level occupational groups
- household crowding
- percentage of parents with no educational qualifications (Ministry of Education 2016).

The indicators used to calculate deprivation scores and decile ratings are very similar. The deprivation score has a transport component so is considered the better option for using in an assessment; however, decile ratings could be considered if a school was located in or near an area under review.

Median household income is a rawer measure than deprivation score, as it only considers reported income. Literature suggests income may not necessarily accurately reflect a household's propensity to use public transport or other mode choice. Some households may decide to purchase a car or additional car to service their travel needs, but the financial hardship they may bear as a result of both the purchase decision and ongoing costs associated with keeping the vehicle(s) on the road is not known (Cheyne and Imran 2010).

The Ministry of Transport (2016) uses the access to a motor vehicle measure as an indicator of a person's ability to access the transport system. For the purpose of evaluating the propensity to use public transport it provides a gauge of the level of dependence on public transport for households in the catchment.

Household composition can vary significantly, so determining the age profile of an area enables an understanding of the types of households living in the study area and can also inform the likely trip types as well as the level of independence of public transport users. For example, should a service be removed from an area that has a predominance of working age adults and few children or elderly the impact is likely to be low, as adults are more likely to switch to an alternative transport mode or increase their walking distance to the nearest stop. Children may not have this flexibility and may have to make the trip

[2] Methods used to control for household composition.

as passengers in other vehicles. Also, a low number of elderly users may also indicate a level of reduced mobility.

6.3.2 Property data

CoreLogic was approached to determine the availability and cost of obtaining property valuation data at either meshblock or suburb level for each study area. This data is not freely available so a scoping exercise was required to determine if the additional cost for the acquisition of this data was advantageous. The outcome of this was CoreLogic was able to supply the 'average sale median' sale price for each suburb in the Auckland and Waikato regions based on the New Zealand fire suburb boundaries.

Rental data (including value of bonds and mean rent) was obtained from the Ministry of Business, Innovation and Employment). This data was in addition to the 'mean rent paid' variable extracted from the New Zealand Census data; however, only available at territorial authority or regional level.

The research team and steering group agreed that neither of these data sets added significant value to the project analysis so data acquisition did not proceed.

6.3.3 Additional supporting data

An important aspect of this research was to understand, in addition to patronage, what other factors contributed to the overall value of a service and a network. A number of other data sets were considered to support this research in addition to electronic ticketing data, and a formal request was made to Auckland Transport and Waikato Regional Council for the following information:

- revenue per route annualised (child/adult/SuperGold/concession)
- service provision cost
- any data or key performance indicators that inform network decisions
- any research findings or outputs indicating an 'option' or 'perceived value' for public transport
- customer satisfaction, community satisfaction or consultation submissions relating to route or time table changes
- Total Mobility trip data.

Both Auckland Transport and Waikato Regional Council were willing to provide as much supporting data as possible; however, due to contract structure and the high commercial sensitivity of revenue and cost data, this data was not available at a specific route level. Variable contract rates were deemed the best cost variable to use and were supplied by each region for use in the technical analysis.

Public transport customer satisfaction surveys are completed regionally and collated by the Transport Agency to monitor consistency of service delivery between regions. The survey questions and measures used in these surveys were reviewed and deemed too broad and qualitative to be of any value to this research. Any survey data would need to be available at route level to be useful to support further analysis.

The Transport Agency provided performance monitoring metrics currently gathered from Auckland Transport and regional councils to monitor public transport network performance and appraise projects for future funding. The structure of this assessment framework was used as a reference in the economic analysis and tool development discussed in subsequent chapters.

The Total Mobility Scheme, funded in partnership by local and central government, provides subsidised taxi services to people with serious mobility constraints that prevent them from assessing and using public transport (NZ Transport Agency 2016a). Auckland, Wellington and Christchurch operate an electronic smart card system to record Total Mobility trips, while other regions use a paper-based voucher system. Total Mobility electronic trip data was not received, so no consideration has been given to how this would be applied.

6.3.4 Data limitations and risks

The general quality and consistency of existing data was highlighted by stakeholders in earlier stages of the research as a risk, due to the lack of an integrated approach to data collection or network metrics. The accuracy and breadth of information currently gathered appears to vary significantly between regions and for some regions is imprecise and highly aggregated. This will remain a challenge until a nationwide integrated ticketing system is successfully implemented in New Zealand.

Data collected from Auckland’s integrated ticketing system with both tag on and tag off facility and geo-referencing was comprehensive, and suitable for extensive mapping and analysis. The absence of tag off data for Waikato, however, provided a challenge to the depth and accuracy of the Waikato analysis due to:

- an inability to accurately determine passenger trip length
- lack of visibility of transfers
- lack of understanding of trip origin/destination and travel patterns.

7 Spatial and temporal analysis

7.1 Overview of methodology

Spatial and temporal analysis was undertaken using the data gathered and outlined in chapter six. The Auckland integrated ticketing data provided the most comprehensive data set from which to develop a case study and test an assessment framework, so the analysis in this section is centred on Auckland using HOP card data, GTFS data feeds and census data. This data was combined to model the impacts of spatial and temporal changes to the value of a component of the Auckland public transport network. The aim of the analysis was to understand not only the trips made on a service, but also the trips it enabled on the greater network, as well as the relationship between the demographic makeup of an area and the social impact a change in service provision has on that community.

A similar approach was planned for assessing a component of the Waikato public transport network; however, limitations with the Waikato data, including no tag-off, no user unique IDs or geo-referencing meant a more simplistic and indicative approach needed to be taken to the spatial modelling and analysis for this case study. This is discussed further in chapter 8 and in appendix B.

This chapter develops a proof of concept for spatial and temporal analysis of the electronic HOP card transaction data and other datasets to demonstrate how this information can be used to measure the value of a service and its contribution to the network as a whole. The same methodology would be directly applicable to any region that has an integrated ticketing with similar reporting and data capture functionality, and is expected to be consistent with the ongoing national integrated ticketing initiative led by the Transport Agency.

7.2 Spatial analysis

The research team reviewed the Auckland public transport network to determine a suitable study area that would allow a 'feeder' service to be isolated and tested to understand the extent to which the available data sets could inform the value of a change in spatial coverage.

The Auckland network is predominately radial with few crosstown or feeder services. Five potential areas were examined for suitability to emulate the characteristics of an area serviced by a feeder route. The key characteristics the evaluation considered were that the area:

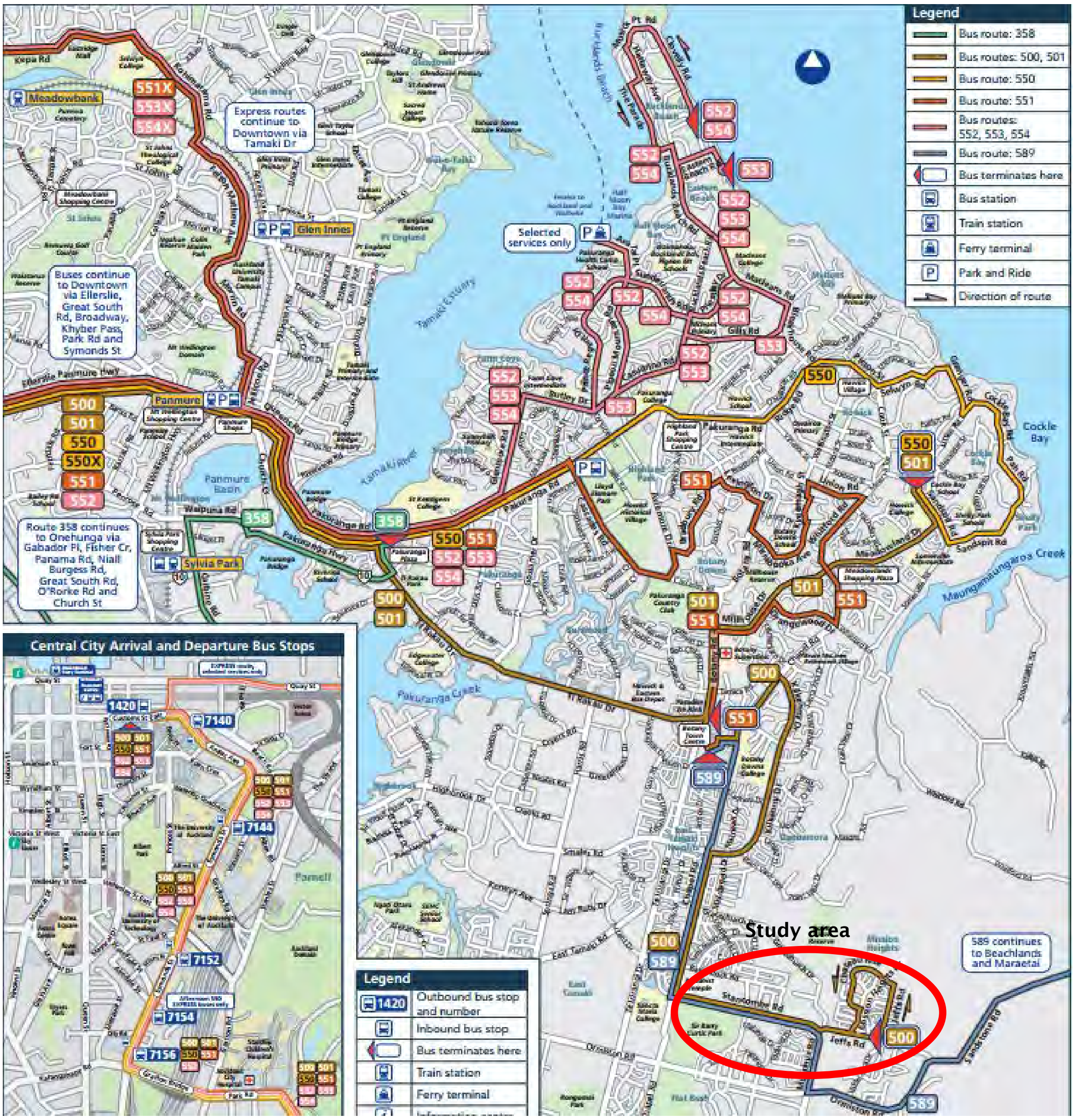
- was serviced by just one bus route (no alternative public transport option)
- was at the end of a route
- generated sufficient trips in HOP card data
- was a residential area
- the topography was generally suitable for walk access.

Mission Heights, serviced by bus route 500 was considered the best example for modelling and examining the value of a network component. The travel characteristics of the study area and service users were analysed to understand the impact a change in service provision in this area may have. The 11 stops selected in the Mission Heights study area represent a component of the network and have been chosen because the end of the service is geographically isolated with the remainder of the route is duplicated by other services. On this basis it is a hypothetical case study for the application of the assessment method only.

A section of 3.8km, which included 11 stops was isolated and considered as the study area for the spatial analysis as highlighted in figure 7.1. Route 500 operates between Downtown Auckland and Mission Heights and is 29.8km long. The key activity centres along the route include Botany Town Centre, Panmure Interchange and Ellerslie shops. The route also services Auckland City and Starship Hospitals as well as 14 schools (Mission Heights primary school, Mission Heights Junior College, Baverstock Oaks school, Willowbank school, Botany Downs Secondary college, St Patricks School, Stanhope Road School, Ellerslie School, Dilworth School Senior Campus, Diocesan School for Girls, Epsom Girls Grammar School, Newmarket Primary School, St Peter's College and Auckland Grammar School).

There is no bus priority in the Mission Heights study area, although there are cycle lanes on the Stancombe Road corridor.

Figure 7.1 Mission Heights study area



Using the HOP card unique ID numbers, trips starting or finishing at one of the eleven stops in the study area were isolated and analysed. The characteristics of the study area have also been analysed by creating a 10-minute walk distance buffer around the 11 stops using the Auckland accessibility model. The 10-minute walk approximates the 85th percentile walk distance in Auckland to access public transport services based on analysis of the Ministry of Transport National Household Travel Survey (Wedderburn and NZ Transport Agency 2013). This provides a measure of the number of households that are likely to access bus route 500 from any of the selected stops in the study area.

Having isolated a component of the Auckland public transport network, the research team interrogated the data sets to determine:

- How many people access route 500 from the 11 isolated bus stops?
- The number of additional trips that are enabled elsewhere on the network for these users as a result of being able to access the network from the 11 stops isolated
- How far are the Mission Heights users travelling across the network?
- If their accessibility to the network changed (addition or removal), how would this affect their travel behaviour?

7.2.1 Data application

The key variables considered in the analysis were demand by route, stop, meshblock area, time of day; passenger journey lengths and travel behaviour on the network. The corresponding data was studied to establish relationships between change of coverage, accessibility and patronage, and the resulting impact on network value.

Public transport accessibility in Auckland was analysed using the previously developed, tested and validated Auckland Transport Accessibility Model (ATAM). The ATAM has route choice and connectivity mechanisms build into it allowing combined walking and public transport networks to be analysed at a sufficiently fine-grained level to enable accessibility measures from individual properties (address points) to be calculated. The ATAM was used to determine accurate walking routes to access public transport taking into consideration the current walk network and crossing points.

7.2.2 Trip distance

Auckland Transport provided HOP card data for all transactions made on the Auckland network on Wednesday 11 November 2015. Using this comprehensive data set, it was established that 229 tag ons by unique card IDs were made from within the study area. In addition to this, these same unique card IDs tagged on again somewhere else outside of the study area another 296 times. These additional enabled trips could be a return journey, or an additional trip elsewhere on the network. There were also a further 50 paper (cash) tickets issued from the study area. The distance travelled and enabled trips made by these cash ticket users is unable to be tracked or analysed.

A summary of the number of trips and average distance travelled by unique IDs from the study area is presented in table 7.1. This is broken down by fare type and shows both the trips that are made from the 11 stops isolated, as well as the additional/enabled trips that occur elsewhere on the network as a result of the boarding by the unique card IDs that tagged on at these stops.

Table 7.1 Transaction summary for Mission Heights 11 isolated stops

	Unique ID trips from Mission Heights 11 stops		Enabled trips outside of Mission Heights	
Fare type	**Number of trips**	**Average distance travelled (kms)**	**Number of trips**	**Average distance travelled (kms)**
Adult	91	17.0	127	13.0
Child	36	6.7	20	9.7
Secondary student	19	10.9	27	10.6
Tertiary student	65	21.6	84	16.8
Senior	18	12.2	38	8.0
Accessible	0	0	0	0
TOTAL	229	15.8	296	12.4
Cash	50			

Appendix C contains a series of graphs showing the distance travelled on the Auckland network as a whole, broken down by fare type. These trip lengths are calculated based on tag ons and tag offs with the HOP card, and they may not reflect the total distance of the passenger's journey if a passenger had to transfer a number of times to complete their journey. This helps inform the travel patterns of public transport users and may provide some guidance to determine what alternate modes of transport would be used if service changes were made that altered accessibility to public transport. For example short trips could be satisfied by walking and cycling.

Key observations include:

- Adults travel a range of distances with a significant number of long trips.
- Children predominantly use public transport for short trips less than 10km.
- The high frequency of 15km trips by adults and tertiary students is likely to be travel to the CBD for work trips or University of Auckland for students.
- The majority of tertiary student trips are in excess of 14km.
- SuperGold card users predominately use public transport for trips less than 16km.

Auckland Transport currently operate a stage-based fare system. When a HOP card user boards a bus, ferry or train, an initial fee is charged to the card. When a tag-off on the card occurs on disembarking, the system calculates the fare and charges for the distance travelled. If a transfer is made to another service within 30 minutes of a tag off corresponding to a previous trip, a transfer discount will be applied.

HOP data received was missing the 'displayed route ID' for a few trip transactions, meaning the stops used were known, but not the service. These trips were excluded from the analysis along with a few additional transactions that had route anomalies.

7.2.3 Trip destinations

The HOP card trip data for the unique IDs originating in the study area was mapped using GIS. This provides a visual representation of where users are travelling to and from, on the Auckland network. It is a useful tool for understanding the value of the individual service in isolation, but also to what degree the service facilitates travel on the wider network.

Figure 7.2 shows the number of boardings by stop made by unique card IDs isolated from the study area in Mission Heights and figure 7.3 shows where the corresponding users alight from public transport services. The stops with a large number of boardings or alightings outside of the study area are generally key activity centres, train stations or the CBD.

This demonstrates that the study area users are travelling extensively on the Auckland public transport network as a result of the current access to public transport, and a number of additional trips are performed by these users.

Figure 7.2 Boardings recorded across the network by users accessing the network from the 11 stops in the study area

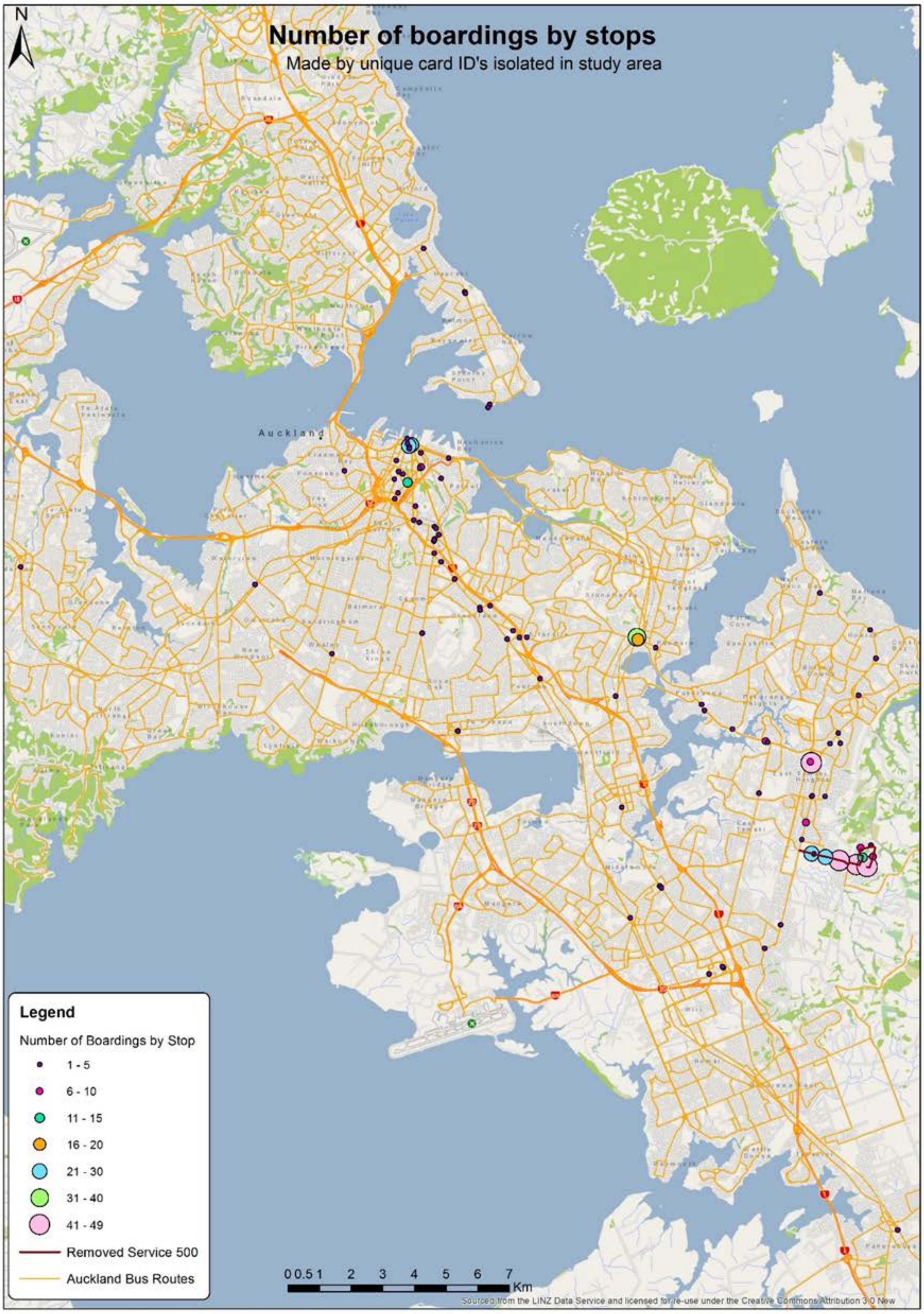
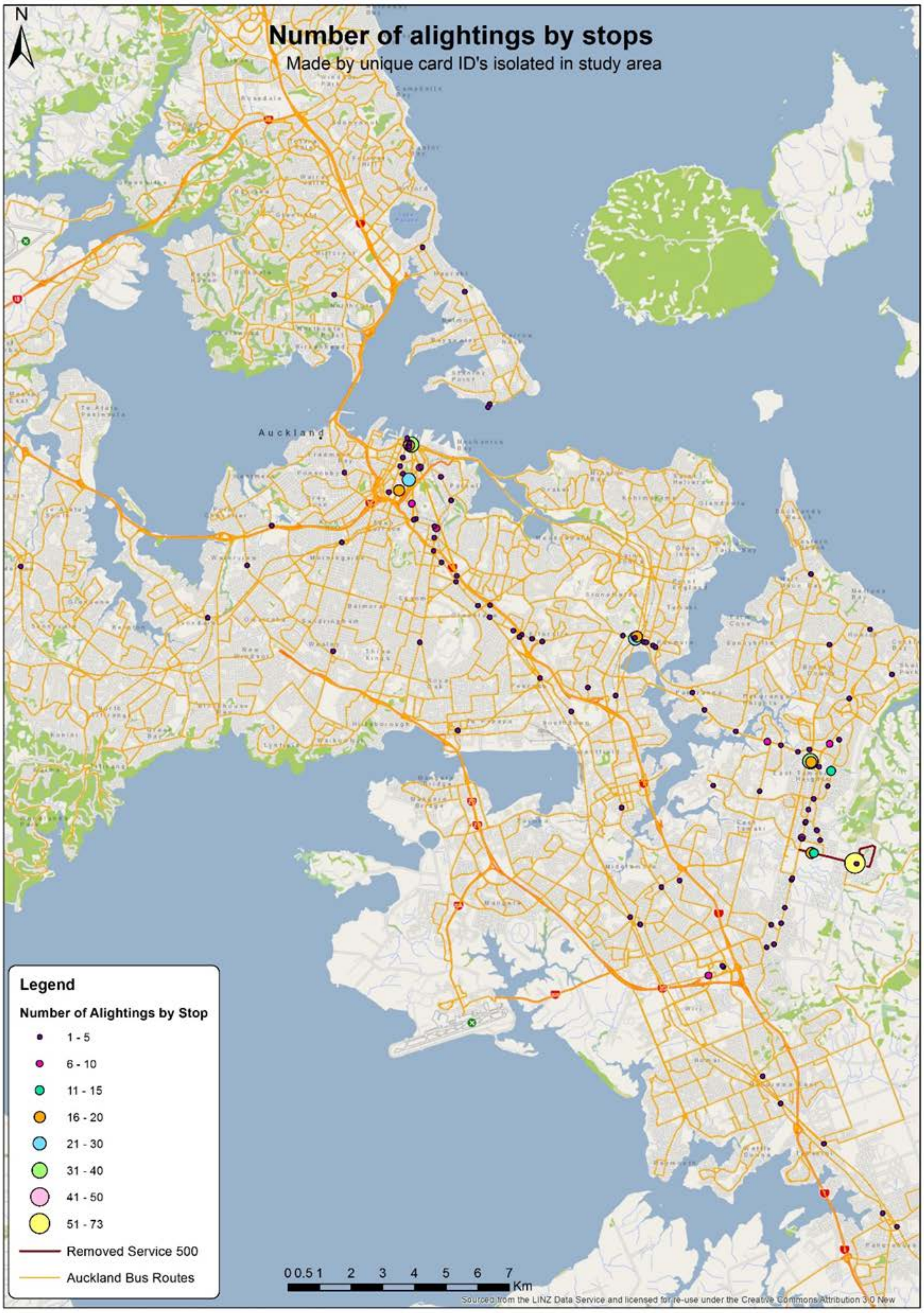


Figure 7.3 Boardings recorded across the network by users accessing the network from the 11 stops in the study area



7.2.4 Study area demographics

The analysis of the integrated ticketing data provides detail and visibility of how many people from the study area are using public transport and where they are travelling on the wider network. The next step was to understand who these users are, and how dependent are they on having good access to the public transport network.

Demographic data for the Mission Heights study area was compiled and analysed at meshblock level to help understand the social drivers that may influence public transport demand in this area. This section provides a demographic overview of the proof-of-concept study area, and demonstrates how to incorporate a fuller understanding of the community under review when appraising public transport services.

There are 2148 households within a 10-minute catchment area of the 11 bus stops at the end of route 500. The median household income is in the range of $80,000 to $100,000 and the median deprivation score is three. The household income and deprivation range and distribution for the study area are summarised in tables 7.2 and 7.3, and shown diagrammatically in figures 7.4 and 7.5. Figure 7.6 illustrates the extend of deprivation in close proximity to the study area.

Table 7.2 Median Income of study area

Median income	Number of households
$60,000 – $80,000	279
$80,000 – $100,000	1062
$100,000 – $120,000	558
$120,000 – $150,000	216
>$150,000	33

Figure 7.4 Median household income in study area by meshblock

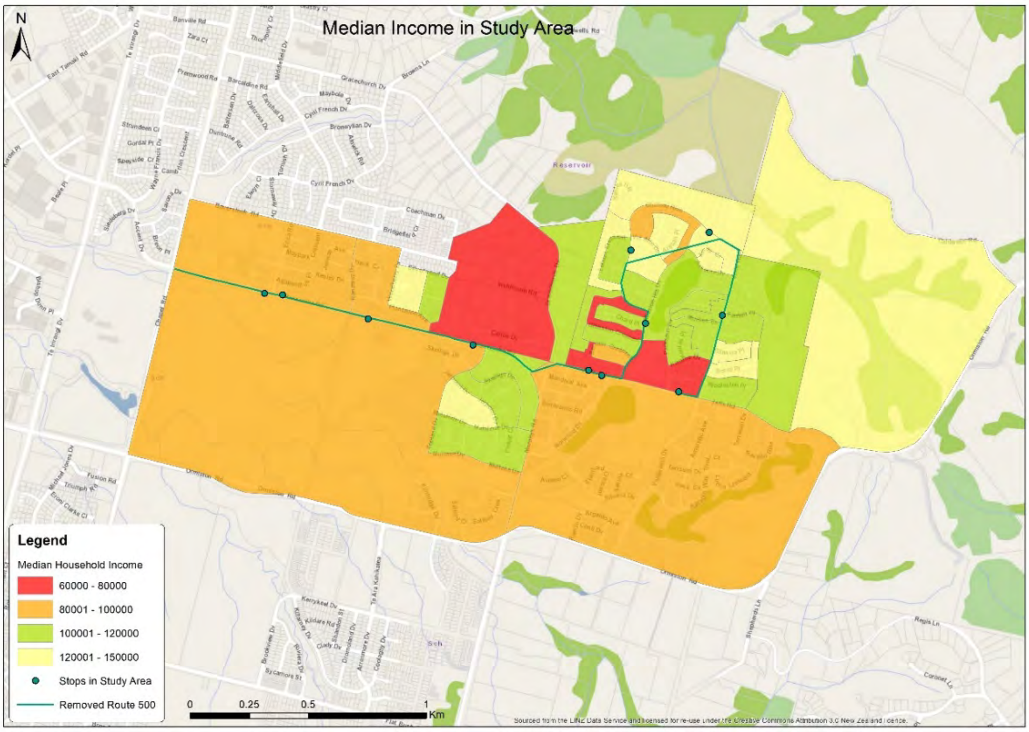


Table 7.3 Level of deprivation of study area

Deprivation index score	Number of households
1	219
2	321
3	708
4	285
5	288
6	327
7	0
8	0
9	0
10	0

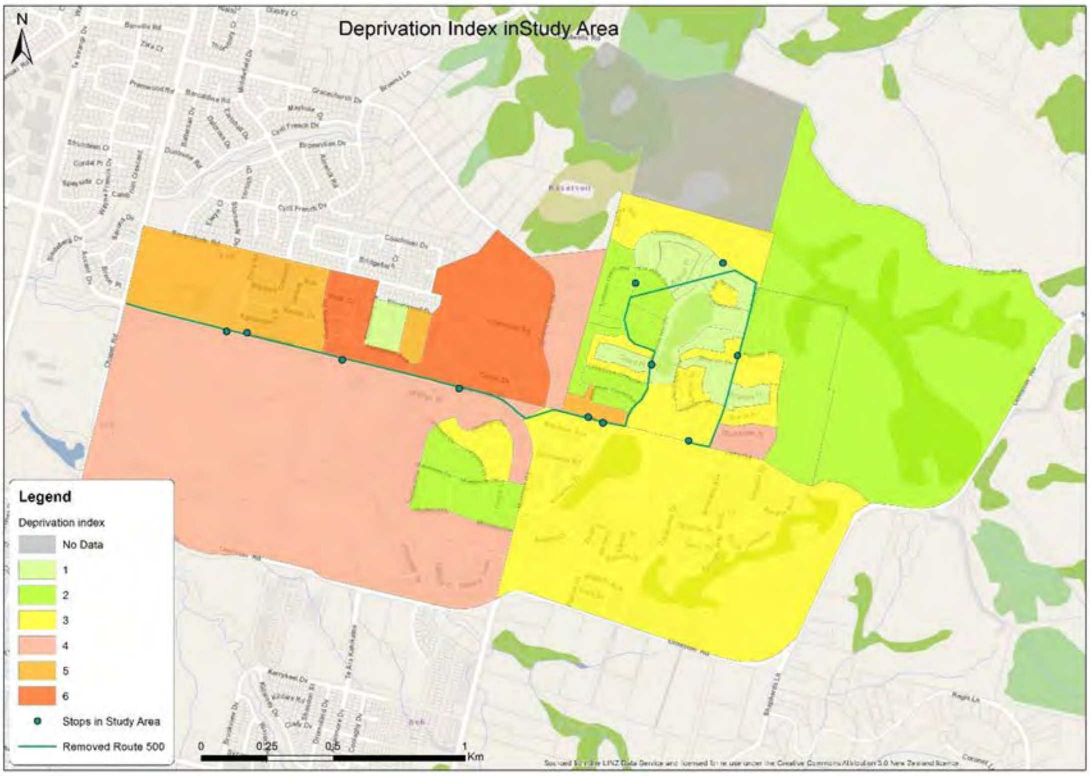


Figure 7.5 Deprivation levels in study area by meshblock

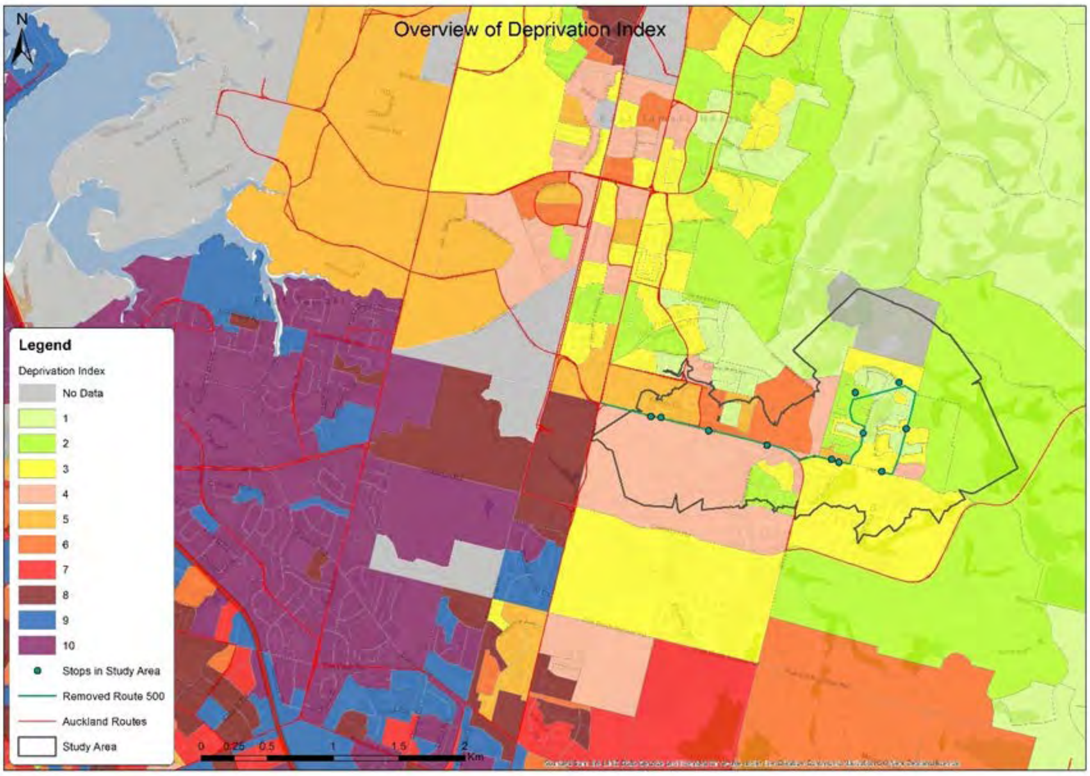


Figure 7.6 **Wider view of deprivation surrounding study area**

Two additional demographic indicators were mapped and analysed: age profiles, and access to a motor vehicle. Age profiles help inform both the likely trip types as well as provide a measure of the likely level of independence of public transport users. The age profiles for the catchment are shown in table 7.4 and indicate that there are a number of households with young children living in the area. The study area has a predominance of adult users, but also a number of children that may use public transport from the isolated stops, as shown in table 7.1.

Table 7.4 **Age profile of the study area**

Age (years)	Transaction type	Number of people in catchment
0 – 14	Child	2052
15 – 19	Secondary student	543
20 – 24	Tertiary student	573
25 – 64	Adult	4683
>65	SuperGold	441

From the census data it is calculated that the average number of vehicles in the study area is 2.28 vehicles per household and 99% of households have access to one or more vehicles. This would suggest that nearly all the households in the catchment have access to at least one car. Statistics New Zealand report the average household size as 2.7 persons per household; however, there is no breakdown as to the number of working age adults per household. Table 7.5 provides a breakdown of the number of vehicles per household in the study area. The census data however is incomplete with some households not recording how many vehicles are available and are therefore not represented in table 7.5.

Table 7.5 Study area access to motor vehicles

Number of vehicles per household	Number of households
0	18
1	357
2	1014
>3	645

7.2.5 Accessibility

The spatial analysis allows the impact of a change in accessibility as a result of a change in service provision to be measured. The purpose of this assessment is to understand the implications a change may have on public transport users. In particular, is the change of walk access time significant enough to force public transport users to switch to an alternative transport mode, or will they be prepared to walk the additional distance to their nearest bus stop?

Table 7.6 lists each of the meshblocks in the study area and provides an example of the change in distance (calculated from the ATAM) to the nearest bus stop (that is on another service) if the last 11 stops (3.8km) of route 500 were removed. Please note that the calculation for these distances is based on the distance from a centre point in the meshblock to the nearest bus stop rather than being calculated from individual households.

Table 7.6 Accessibility measures of meshblocks in catchment areas

MB 2013	# of households	Current access distance to service (m)	Access distance with service removed (m)	Additional access distance (m)
0712203	198	642	758	117
0712500	477	480	1,235	755
0712121	222	220	489	269
0712122	129	518	587	69
0712124	39	611	692	81
0712125	39	466	808	342
0712204	0	325	1,537	1,212
0712205	18	163	1,440	1,277
0712206	36	540	667	127
0712207	15	196	1,394	1,198
0712208	21	140	1,170	1,030
0712209	30	166	1,346	1,180
0712210	27	210	1,284	1,074
0712211	24	217	1,158	941
0712212	24	210	1,027	818
0712213	21	391	831	440
0712214	24	211	1,022	812
0712215	18	127	902	774
0712216	30	295	734	439

MB 2013	# of households	Current access distance to service (m)	Access distance with service removed (m)	Additional access distance (m)
0712217	15	209	649	440
0712218	24	255	695	440
0712219	27	300	1,352	1,052
0712220	12	287	1,344	1,056
0712221	21	289	1,169	881
0712222	18	331	1,211	880
0712223	15	369	1,230	862
0712224	24	345	1,062	717
0712225	27	288	971	684
0712226	33	132	804	672
0712228	33	283	1,498	1,214
0712229	24	181	1,245	1,065
0712230	24	211	1,022	911
0712231	21	337	1,116	779
0712232	27	254	1,033	779
0712401	189	459	867	409
0712402	36	202	302	100
0712403	57	412	688	275
0712404	39	366	745	379
0712405	93	584	680	96
0712227[a]	6			
Total households	2,148			
Average distance		403	916	513

[a] This meshblock is only partially in the catchment and change in access not calculated as the houses in the meshblock are closer to an alternate bus route to the north

The change in walk distance for the meshblocks in the catchment ranges from an increase of 69m to 1,277m with an average increase of 513m to the nearest bus stop when the 11 stops at the end of route 500 are removed. Based on a typical walk speed of 4km/h this represents an increase in walk access time of up to 19 minutes with an average increase of eight minutes to access the next nearest bus service when the 11 bus stops in route 500 are removed.

The assessment also needs to consider the number of effected users based on the number of households in each meshblock. Meshblock 712500 has the greatest number of households in it and the increase in walk distance is significant (755m). Following the change, the average walk access distance for these households would be 1,235m, well in excess of the 800m threshold. The second largest meshblock (0712121) experiences an increase in walk access distance of 220m, but the total new walk distance is still short at 489 m. In summary, following the change in the public transport service tested in this example, 42% of all the households in the study area would still be within 800m of a bus stop.

Figure 7. 7 displays the meshblocks within a 10-minute walk distance catchment/study area, the 11 bus stops that could be removed as part of a service review, and the proximity of the next closest stops (that

are serviced by another route). It is noted that the relative attractiveness of these nearby services will also be sensitive to the extent of connectivity to the wider network provided by each service as well as the frequency and directness of these alternative bus services.

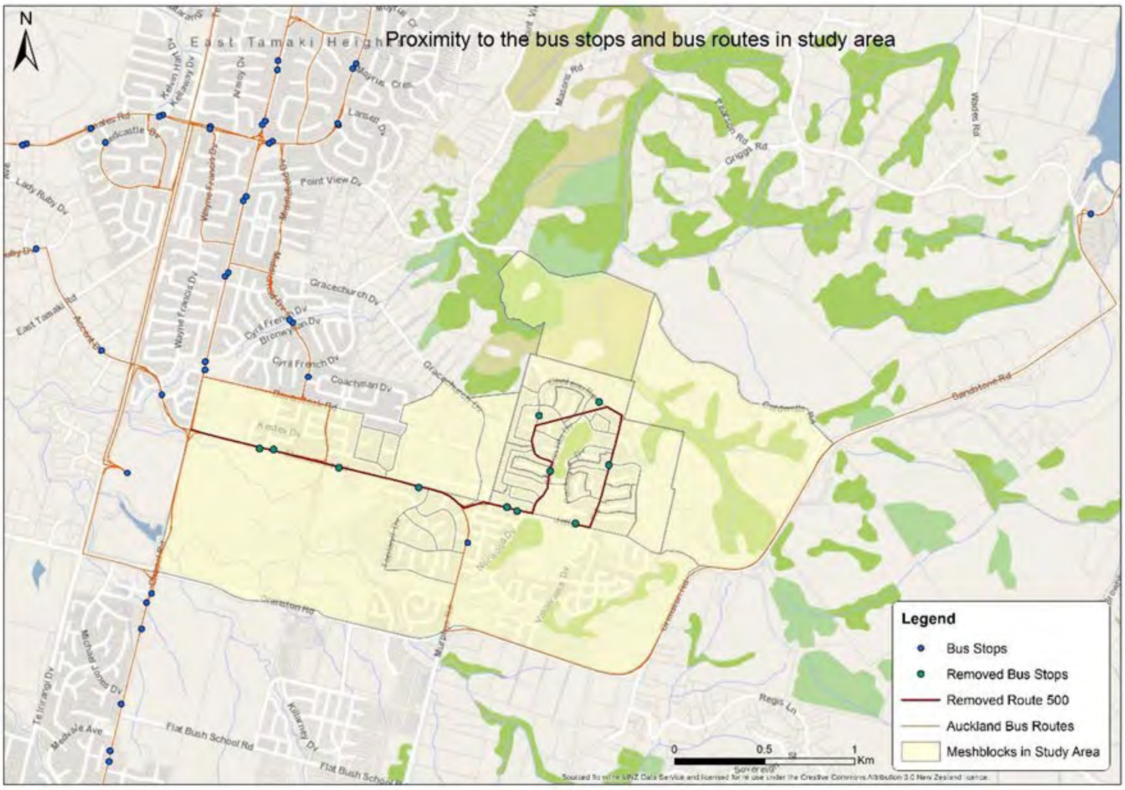


Figure 7.7 Proximity of alternate bus stops to catchment

7.2.6 Spatial analysis overview

There are a number of data sets and analyses that have been presented in this section and can collectively provide the foundation for an assessment of the value of public transport as a network when a change in spatial coverage is considered by public transport planners. The following data sets have been demonstrated and used to complete a case study assessment in chapters 9 and 10 of this report:

- integrated ticketing data to understand the number of patrons affected and the distance they travel across the network by fare (as a proxy for user) type,
- demographic data to understand how many households are in the affected catchment and how vulnerable they are likely to be to changes in service provision based on a deprivation score and related demographics,
- accessibility analysis to determine the change in walk access to the public transport network and inform the extent by which affected users are likely to continue to use public transport,
- an approach to assess the walkability of the local footpath and crossing facilities in the general vicinity of the service, and
- estimate the likelihood of a change in mode.

7.3 Temporal analysis

The second proof of concept presented considers route 500 and the extent to which the available data sets can be used to assess the value of a change in temporal coverage. Route 500 in its entirety has been selected, and the purpose of the temporal analysis is to assess the impact on trips as the result of a change in service hours.

A key factor in the decision to use public transport is the extent to which the public transport network can also provide for subsequent trips, including a return trip, that meets the travel needs of the user for location, frequency and timing. Changing temporal coverage or a service at one (or both) end(s) of the day may result in the temporal coverage meeting (or no longer meeting) the needs of some users who subsequently choose not to use public transport.

To understand the extent to which this may be the case, analysis of the 11 November 2015 HOP card data set was completed to consider the effects of removing timetabled services scheduled to begin between 7pm and the end of daily services at 11pm. In the following sections the affected users are referred to as 'evening bus users' and this corresponds to seven outbound (to CBD) and nine inbound (from CBD) timetabled services.

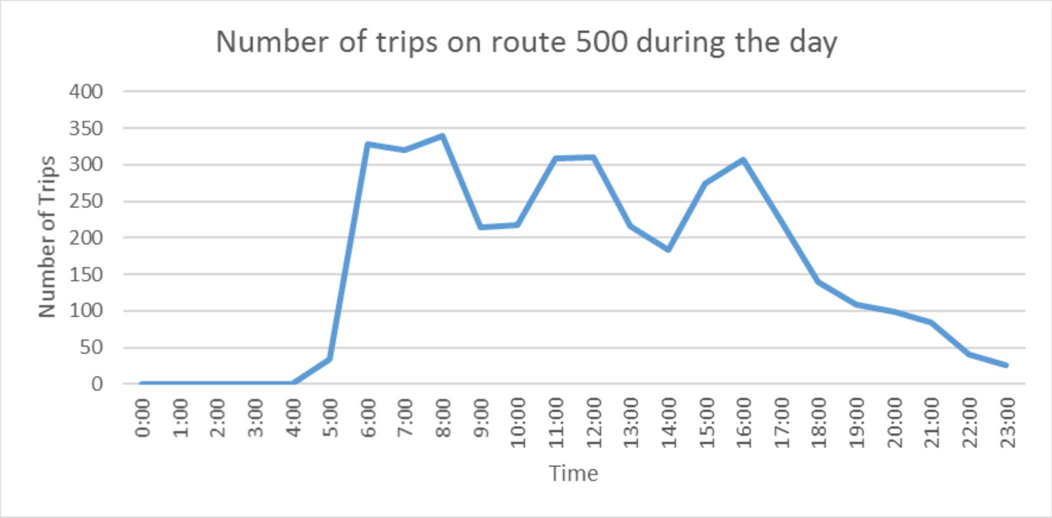
There were 358 trips made on the route 500 scheduled services after 7pm, which equates to an average of 22 patrons per service. This represents 9.48% of the total 3,775 trips on route 500 over the whole day. Of the unique ID cards used on trips after 7pm, these users made 503 other trips on the whole network over the whole day, of which 61 trips (many of which are likely to be transfers to/from route 500) were made after 7pm. A summary of the trip totals is included in table 7.7

Table 7.7 Summary of temporal analysis

	Trips on route 500 over the whole day including after 7pm	Trips on route 500 after 7pm	Other trips made on the network over the whole day by evening users of route 500	Trips made on other routes after 7pm by evening users of route 500
Adult	1,669	179	289	36
Child	211	5	4	1
Secondary student	208	17	19	2
Tertiary student	1,180	146	173	18
SuperGold card	497	10	15	4
Accessible	10	1	3	0
TOTAL	**3,775**	**358**	**503**	**61**
Cash tickets	755	64	-	-

The number of trips occurring on route 500 are presented to illustrate the boarding times by time of day across a typical weekday in figure 7.8. The morning, lunch and evening peak travel periods are clearly depicted, as well as the relatively consistent use of the service after 7pm.

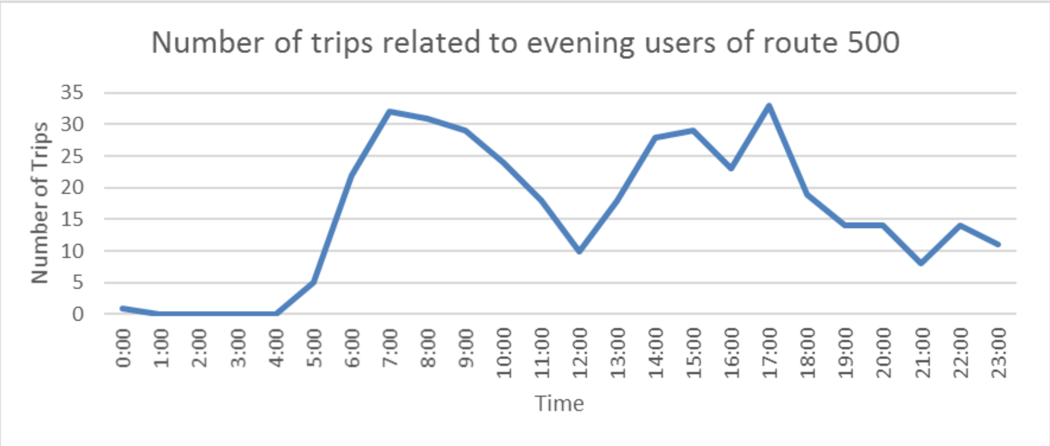
Figure 7.8 Boarding time of trips on route 500



Users were anonymously identified through unique IDs to determine those route 500 patrons after 7pm who made other trips on the public transport network throughout the day.

Figure 7.9 presents a time profile for the additional 503 trips identified on the network by the evening route 500 users. This graph depicts the number of trips occurring earlier in the day across all routes that are undertaken by these evening users.

Figure 7.9 Time of day of trips made by evening users of route 500

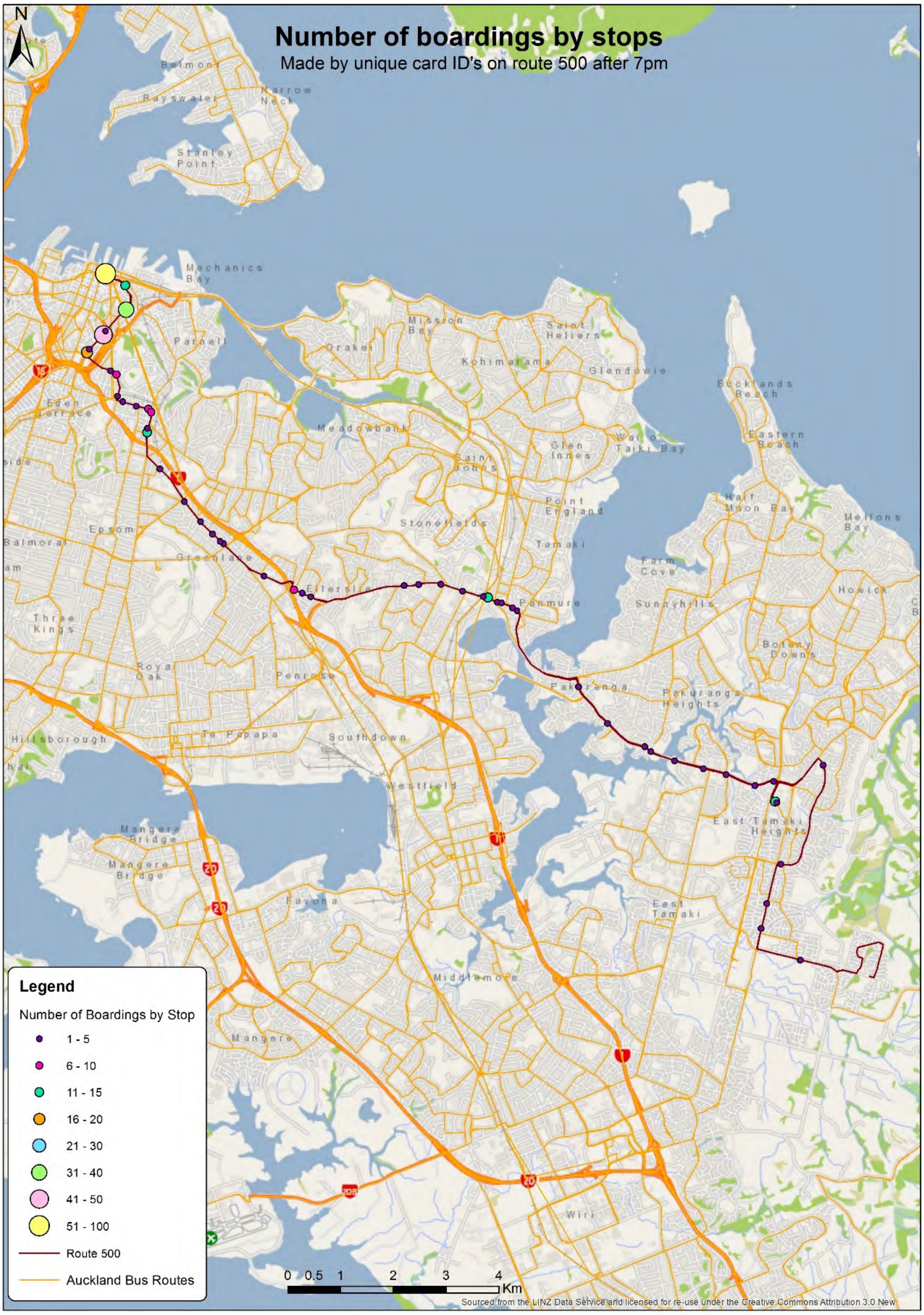


These graphs exclude 120 trips which could not be plotted as the time was unknown from the card transaction data. While these trips are identified as being undertaken by route 500 evening bus users and have been included in a broader assessment of the value of temporal changes in service provision they can not be accurately time-stamped.

The trips made by users of route 500 are shown spatially on the following pages. Figure 7.10 shows where boarding occurred for the 358 trips on route 500 after 7pm, and figure 7.11 displays the location of boarding for the other trips made on the whole Auckland network over the day by the same evening service users.

These findings are consistent with research undertaken by Currie and Loader (2009) that suggests evening services enable a large number of daytime trips to occur. Their analysis found that where services were extended into the evening, about half of the ridership growth occurred during the daytime when no changes to services had been implemented.

Figure 7.10 Trip boardings made by users of route 500 after 7pm



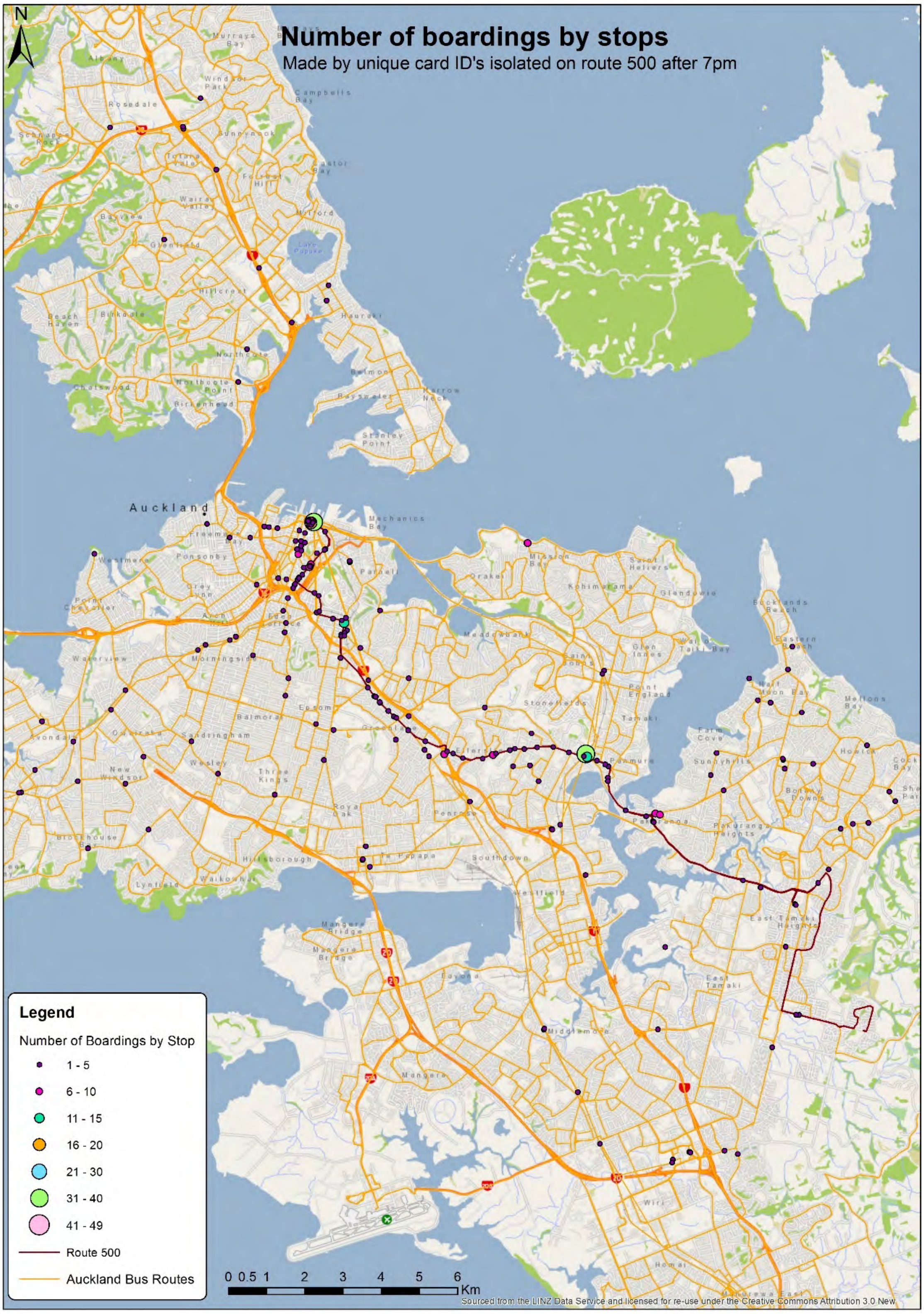


Figure 7.11 Trip boardings made on the network over the whole day by users of route 500 after 7pm

7.3.1 Trip distance

Table 7.8 presents a summary of the average distance travelled by route 500 evening users. This is broken down by fare type and shows the distance travelled on both trips made on route 500 after 7pm, and the other trips made on the Auckland network by the route 500 evening users.

Table 7.8 Trips distances of route 500 evening users

	Trips on route 500 after 7pm	Trips on other services on Auckland network
Fare type	**Average distance travelled (km)**	**Average distance travelled (km)**
Adult	9.30	6.31
Child	14.89	10.29
Secondary student	14.80	8.5
Tertiary student	10.25	8.09
SuperGold card	12.06	6.54
Accessible	2	5.20
TOTAL	10.08	7.04

Appendix C contains a series of graphs showing the range of distances travelled by route 500 evening users both on route 500, as well trips on additional services on the Auckland network undertaken by route 500 evening bus users as a whole, broken down by fare type. These distances are calculated from tag on and tag off data, therefore may not reflect the total distance of the passenger's journey if a passenger had to transfer a number of times to complete their journey. These graphs show the number of additional trips and corresponding distance travelled which may not have been undertaken using public transport if travel after 7pm on route 500 was not available. Key observations include:

- The majority of additional trips are made by adults and tertiary students.
- Trips after 7pm may have a high social value for these users.
- Trips generally are for distances less than 20km
- The one trip after 7pm for the wheelchair user facilitated three additional trips. The ability to perform these additional trips may have saved taxi fares or Total Mobility funded trips and is likely to have a high social inclusion aspect for this user.

7.3.2 Evening user demographics

The demographics of the evening users could be calculated and analysed in the same way as in the spatial analysis; however, these would have less weight due to the increased travel choice during the day. The majority of route 500 is serviced by a number of routes with services running after 7pm, so to analyse the demographics of users who lose public transport access completely after 7pm, a catchment around route 500 where there are no other services after 7pm would need to be established. However, the analysis was not completed due to the limited value that could be drawn from it.

7.3.3 Application

This section has provided an example of how a variety of data sources can be used to assess public transport at a specific area or route level. Many aspects contribute to determining the value of public transport coverage across the network. Having the ability to isolate trips, trip distances, and user behaviour and make up, allows a more comprehensive evaluation of the value of a public transport service. Aggregating ticketing data and varying both spatial and temporal aspects of individual services provides the ability to assess the impact of a change in service provision on the network as a whole to be measured and valued.

The proofs of concept demonstrate the data sets can be integrated to learn more about:

- how many people are affected
- what additional trips are performed or enabled for these people
- how far do these users travel through the network
- how vulnerable users may be to changes in service provision based on broad social and accessibility indicators.

The following two chapters build on these proofs of concept demonstrating how the value of a network component or network can be enumerated through the application and modification of economic evaluation procedures and then by measuring the impact and value as far as possible based on social and accessibility impacts.

8 Economic analysis

This chapter presents the application and modification of the Transport Agency's economic evaluation procedures to support a cost–benefit analysis of the value of an addition or removal of a component of a public transport network. Using the simplified procedures, the data gathered and analysed in the previous chapters is applied to illustrate a methodology for quantifying the value to the network as a whole.

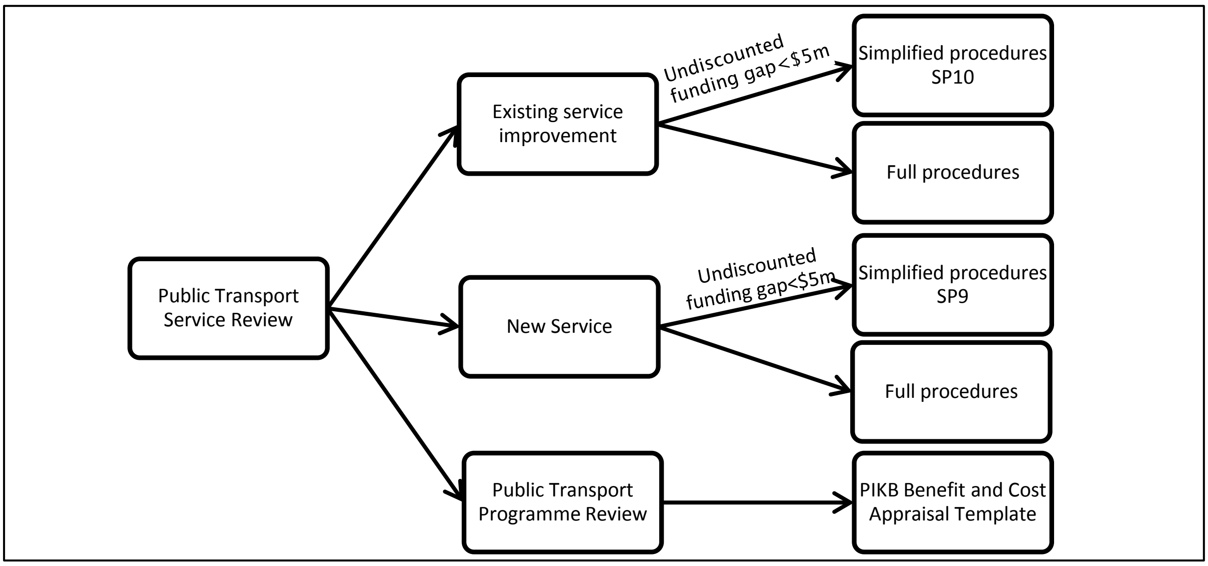
8.1 Background

The Transport Agency assesses activities through the implementation of the Investment Assessment Framework (IAF). This takes a multi-criteria approach to determine the extent to which proposed activities meet the Government's investment strategy, set out in the GPS (MoT 2015). An assessment profile is developed that considers strategic fit, effectiveness and benefit and cost appraisal to provide a rating for inclusion in the NLTP (NZ Transport Agency 2015). The Transport Agency requires the application of procedures and templates in the EEM to determine the benefit–cost ratio (BCR) or measure of the efficiency of a public transport services project.

Simplified procedures SP9 and SP10 are applicable for most new passenger transport services and existing passenger transport services assessments respectively, and can be found in the EEM. The EEM lists a number of assumptions behind the simplified procedures, and suggests either modifying the simplified procedures or applying full procedures in cases where the assumptions are not appropriate. Benefit and cost appraisals for public transport programmes use an appraisal template that incorporates both cost effectiveness and comparative benchmarking as part of the assessment. This resource is available from the Planning and Investment Knowledge Base[3].

The economic evaluation process required is determined by the type of public transport service review being appraised. Figure 8.1 provides an outline of the most appropriate evaluation procedures to be followed for different types of evaluations.

Figure 8.1 Guide to determine the most appropriate evaluation procedures



[3] www.pikb.co.nz/assessment-framework/benefit-and-cost-appraisal/public-transport-programme-benefit-cost-appraisal/

8.2 Application of SP10

The research team applied and modified the simplified procedures template (SP10) to understand how it could be used to assess the value to the network of a change in service provision – specifically, to evaluate any additional incremental value added to the network by services that in isolation might be comparatively inefficient. This provides a basic economic assessment, from which additional consideration can be given to non-monetised elements such as social and accessibility impacts (which are addressed in chapter nine).

The case studies involve the assessment of a change in spatial or temporal coverage, and following the SP10 procedures is considered to be an appropriate assessment if the funding gap is less than five million dollars. The application of SP10 provides an indication of the marginal value of the spatial or temporal portion of the service under review.

The guidance provided in this section explains how to interpret SP10 procedures to generate an economic and value assessment of a public transport service provision change, taking into consideration the value of public transport as a network. At the time of writing this report there is no user guide to support practitioners in populating SP10. This section provides guidance on how the value of public transport as a network can be enumerated using SP10 but does not provide step-by-step guidance to direct users to follow the simplified procedure framework. This chapter should be read in conjunction with a blank SP10 spreadsheet and supporting sections of the EEM for reference and clarity.

SP10 comprises five worksheets to be completed using a number of inputs which can be obtained from regional council data or extracted from integrated ticketing data using GIS or other format analysis. The worksheets are available online from the Transport Agency[4] (and contain a number of helpful prompts as to what information is required in each field. Table 8.1 contains an overview of the SP10 layout and function of each of the worksheets contained in it. The following sections provide an overview of how to complete each worksheet to calculate a BCR to assess the value of a spatial or temporal change in service coverage. The same general assumptions would apply to a full procedures evaluation.

Table 8.1 SP10 overview

Worksheet	Description	Purpose
1	Evaluation summary	Provides a summary of the general data used for the evaluation. Key inputs required include: • peak traffic volume • existing annual and peak period boardings • new/lost patronage as a result of review • proposed user charge BCR automatically calculates once other worksheets are populated.
2	Service provider costs	Calculates the additional service provider costs resulting from a change in service provision. Inputs required are additional annual capital and operation and maintenance costs. Automatically costs the present value (PV) of costs.
3	Funding gap analysis	Calculates PV of funding gap to determine commercial viability of change in service. Key inputs are • proposed user charge

[4] www.nzta.govt.nz/assets/resources/economic-evaluation-manual/economic-evaluation-manual/docs/sp10-pt-existing-services.xls

Worksheet	Description	Purpose
		• operator costs • total projected trip/patronage demand in year two following service change.
4	Net benefits	Calculation of road traffic reduction benefits and additional public transport user benefits using applicable values extracted from table SP10.1. These rates incorporate road user travel time, crash and vehicle operating costs savings, and environmental benefits.
5	BCR and incremental analysis	BCR calculation and to compare options. This sheet was not used in the case study examples.

8.2.1 Evaluation summary (SP10-1)

The first half of worksheet one (SP10-1) is used to provide a brief description of the network component undergoing assessment, including location, length, organisation and timing of the project. The period of analysis for public transport improvements is 15 years. The length of the route or coverage area under review is placed in 'Length affected by use of public transport'. The second half of the inputs for this worksheet relate to annual existing and future patronage numbers. Field 7 requires the number of existing passengers using the service per annum (peak and off peak), as well as peak period passenger numbers to be isolated. In the absence of annual boarding figures, the HOP card boarding data for a typical day can be multiplied by an annualisation factor to get a proxy of likely annual boardings. The annualisation factor of 320 has been applied in the case study examples shown in tables 8.2 to 8.4 to provide an estimated annual patronage figure. This factor was chosen to stay consistent with that applied in *NZ Transport Agency research report 537* (Wedderburn 2013). The percentage of peak passengers is also obtained from the boarding data.

The calculation of passenger numbers for evaluating the proposed service changes needs to consider the likely change in public transport use that may occur as a result of a change in service provision. This is incorporated into the assessment in SP10-1 field 8, and SP10-3 field 6 where the estimated total passenger trips in year two are stated. For the Mission Heights spatial change example, the mode shift rate used has been approximated using the change in accessibility analysis where meshblocks that are no longer within 800m of a bus stop are assumed to switch public transport trips to another mode. The temporal example uses a 50% change in public transport use which draws on work by Currie and Loader (2009), which found where services were extended into evening hours, about 50% of patronage growth that occurred during the day was as a direct result of the addition of the evening services. The calculation of mode shift in the Waikato examples is informed by the origin–destination survey where bus users were asked to state their mode choice if public transport had not been available. A more comprehensive discussion and explanation on mode shift is included in section 9.3.

Field 8 considers the likely new passengers and analyses the future scenario proposed. Using the example of the Mission Heights study area, this is the number of boardings attributed to the 11 isolated stops. It would also include the additional boardings made elsewhere on the network by these users if the value of the additional trips enabled on the network was also being considered. The diversion rate from car drivers to public transport service passengers is stipulated in table SP9.1 in the EEM and the growth rate is held at 0% for the purpose of assessing any additional incremental value that is added to the network by individual services. The proposed user charge is entered in field 9 and this denotes the current average fare over the network. It is noted the update factor in field 12 is published in the EEM, table A12.3 and is updated regularly.

The proposed user charge is the average fare for the region under analysis. This has been calculated by dividing the total revenue by the total patronage for the 2014/15 financial year.

8.2.2 Service provider costs (SP10-2)

Worksheet two considers the additional capital and operation and maintenance costs associated with the change in public transport service provision. Any additional bus (including driver labour) or kilometre requirements, can be calculated using the operator variable contract rates. The capital cost is a one-off cost in year one, and the additional operation and maintenance cost is annualised for the 15 years of the evaluation.

8.2.3 Funding gap analysis (SP10-3)

This worksheet calculates the funding gap to assess the commercial viability of the activity. The funding gap is the level of investment required by local or central government to meet the service providers return on investment in providing the transport services (EEM, NZ Transport Agency 2016b). The case study assessments use a service provider rate of return of 12%. The key input on worksheet three is line 6 ‘Estimated total passenger trips per annum from year 2’. This is calculated by adding the total existing passengers originating from the study area, plus the additional passenger boardings of the passengers using the stops isolated for analysis. If the example being calculated is also valuing the additional trips enabled on the network by the users of the isolated stops, these additional trips would also be added into this boardings figure. The difference between the existing passengers (line 3) and the estimated total passenger trips from year 2 (line 6) gets multiplied by the proposed user charge to populate the revenue (10) figure. The cost component is carried forward from worksheet two and embedded formulas calculate the funding gap.

8.2.4 Net benefits (SP10-4)

Benefits accrue to public transport and road users as a result of road traffic reduction and congestion (EEM, NZ Transport Agency 2016b). For the purpose of this analysis, the focus of worksheet four is on calculating the service benefits for the period of the day that is being assessed. This is done by selecting the applicable road traffic reduction and public transport user benefit rate from the EEM, table SP10.1 which is included at the bottom of the worksheet. The road traffic reduction benefit incorporates travel time savings, congestion reduction, vehicle operating cost savings, crash cost savings, and environmental benefits (including CO_2 reduction).

8.2.5 Additional assumptions

In general, the SP10 simplified procedures are appropriate for calculating a BCR for assessing the value of a temporal or spatial network change to the network as a whole. There are several underlying assumptions that need to be considered when adapting SP10 for this purpose. These assumptions include:

- The improvement to services will be implemented in the peak period, on a road corridor that has a minimum of one point operating at least at 80% capacity during peak periods. If this is not the case, off-peak benefits only should be used.
- A separate SP10 evaluation is required for the peak and off-peak periods. These are then added together to capture the different benefit rates attributed to each period.
- The calculation of transport services user benefits and road traffic reduction benefits (including travel time, vehicle operating cost, and crash cost savings, reliability and environmental benefits is simplified.

- The additional transport service user benefits/disbenefits accrue to both existing and new users as a result of the service changes (EEM, NZ Transport Agency 2016b).

The benefit values assume each trip on the service is of an 'average' length for an urban centre as stated in the EEM, table SP10.1. If trip lengths are significantly shorter or longer for the service or area being evaluated, the passenger numbers can be adjusted to reflect a more representative trip length. This avoids overstating or understating the benefits.

The value of additional trips on the network that are enabled as a result of access to a service also need to be included in the evaluation. This concept is quantified through adding in additional boardings outside the review area by users who originated in the review area.

The marginal cost of service provision must also be considered. Where service coverage is in place at the end of a route to facilitate turning a bus around, the marginal cost of providing this additional coverage is very low. Any adjustment to service provision will be sensitive to contractual obligations and contract terms.

8.3 Case study one – Auckland (Mission Heights)

The purpose of the first case study is to demonstrate how the modifications to SP10 provide a better representation of the value across the network resulting from a spatial change in service provision (section 8.3.1) and a temporal change in service provision (section 8.3.2). These build upon the data analysis and case study presented in detail in chapter seven.

Four evaluations have been completed using the EEM's SP10 worksheets to assess the impact on network value as a result of a change in service provision. The first project evaluation considers the BCR using default values while the additional evaluations show the change in BCR as consideration is given to the value of enabled trips and adjusted trip length in isolation, and then together. These are added into the appraisal for a spatial change and shown in table 8.2. The application of SP10 without any modifications demonstrates that the component of the network isolated in Mission Heights has a BCR of 1.8 and 42,000 passengers per year using this section of the route. Using the integrated ticketing data, additional trips taken on the network by users in the study area are able to be added to capture their additional value. These trips increase the BCR to 3 and the number of passenger trips affected to 96,000 per annum, as there are 54,000 further trips on the network by Mission Heights residents. This analysis enumerates this component of the network and provides a measure of the change in value should this section of the service be added or removed.

The third evaluation adjusts the trip length to be reflective of the actual average trip distance made by Mission Heights users. The 6.60km average trip length stated in the EEM, table SP10.1 (and fixed into the SP10 spreadsheets) was significantly lower than the average trip length of 15.8km per trip extracted from the integrated ticketing data. The SP10 worksheets do not allow trip length to be adjusted, so in order to account for this, the passenger trip numbers were divided by 6.60 (average bus/ferry trip length for Auckland) and then multiplied by 15.8 to provide an equivalent passenger count that more accurately reflects the actually trip distance travelled. The resulting BCR is 4.1 and the equivalent of 100,244 passengers[5] being affected. The final evaluation considers both the enabled trips and adjusted trip length resulting in a BCR of 6.4, 201,935 affected passengers, and operating at a commercial level.

Tables 8.2 and 8.3 provide a summary of the economic assessments for each of the project evaluation methods for the Auckland case study area. The proposed user charge is the average fare for the region

[5] In the SP10 evaluation spreadsheets the average trip length is fixed. In order to circumvent this passenger numbers have been adjusted to recognise the higher trip lengths.

under analysis. For the purpose of this research assessment, this has broadly been calculated by dividing the total revenue by the total patronage for the 2014/15 financial year.

The SP10 modifications demonstrate that providing a framework for incorporating the value of trips enabled from services that in isolation appear inefficient, and adjusting for trip length significantly increases BCRs; in this case from 1.8 to 6.4.

The funding gap is less than five million dollars for all four scenarios validating the use of SP10, in preference to full evaluation procedures; however, the same principles apply to both methods of evaluation.

8.3.1 Spatial service review

Table 8.2 Example of BCR calculation for spatial service change

Extend of project evaluation	Trip length assumption	Period	BCR	Additional route length (km)	Average trip length (km)	Existing pax on service	Existing peak pax	New pax on subject service	Rate of growth[6]	Proposed user charge[7]	PV funding gap
No enabled trips	SP10 default	Peak	1	3.8	6.6	1,208,000	352,445	12,217	0%	$2.18	$1,411,121
		Off peak	0.8					29,657			
		Combined	**1.8**					**41,874**			
Including enabled trips	SP10 default	Peak	1.2	3.8	6.6	1,208,000	352,445	28,009	0%	$2.18	$607,479
		Off peak	1.8					67,991			
		Combined	**3.0**					**96,000**			
Adjusted trip length	Adjusted based on spatial analysis	Peak	2.3	3.8	15.8	1,208,000	352,445	29,247	0%	$2.18	$544,458
		Off peak	1.8					70,997			
		Combined	**4.1**					**100,244**			
Adjusted trip length plus enabled trips	Adjusted based on spatial analysis	Peak	2.5	3.8	13.88	1,208,000	352,445	58,917	0%	$2.18	-$965,414
		Off peak	3.9					143,019			
		Combined	**6.4**					**201,935**			

[6] Ordinarily captured via a transport model or based on demographic growth. Zero percent growth used for the purpose of this example analysis.

[7] The proposed user charge is the average fare for the region under analysis. This has been calculated by dividing the total revenue by the total patronage for the 2014/15 financial year.

8.3.2 Temporal service review

The temporal review considers the same four scenarios as the spatial analysis, although only considers the off peak, as the evaluation is to consider the value of evening services from 7pm onwards when the network is not congested. Table 8.3 shows the value of the enabled trips, as a result of evening services being in place, is significant. Valuing the enabled trips with the default trip distance generates a BCR of 3.9, increasing to 4.8 when the trip distance is adjusted to reflect the integrated ticketing data. The number of passengers utilising evening services in this area of the network range from 57,280 in the most conservative analysis to the equivalent of 171,620 when both enabled trips and adjusted trip lengths are considered.

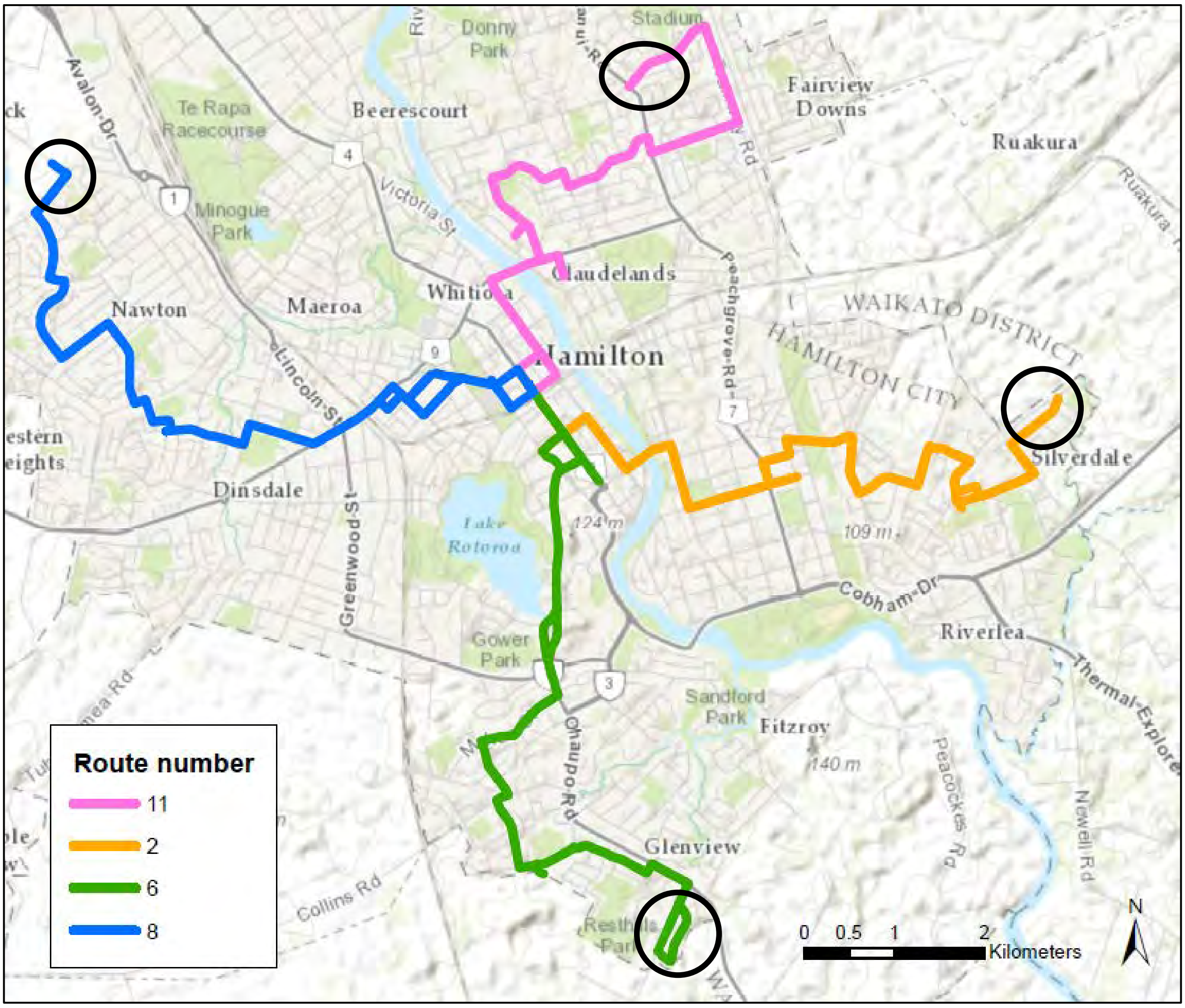
Table 8.3 Example of BCR calculation to value services beyond 7pm on route 500

Extend of project evaluation	Trip length assumption	Period	BCR	Additional route length (km)	Average trip length (km)	Existing pax on service	Existing peak pax	New pax on subject service	Rate of growth	Proposed user charge	PV funding gap
No enabled trips	SP10 default	Off peak	1.6	29.8	6.6	1,208,000	380,800	57,280	0%	$2.18	$1,123,956
Including enabled trips	SP10 default	Off peak	3.9	29.8	6.6	1,208,000	380,800	137,760	0%	$2.18	-$70,986
Adjusted trip length	Adjusted based on spatial analysis	Off peak	2.4	29.8	10.08	1,208,000	380,800	87,482	0%	$2.18	$675,524
Adjusted trip length plus enabled trips	Adjusted based on spatial analysis	Off peak	4.8	29.8	8.22	1,208,000	380,800	171,620	0%	$2.18	-$573,734

8.4 Case study two – Waikato

The purpose of the second case study is to demonstrate how potential spatial service changes can be compared and contrasted in a regional centre using the proposed modified SP10 framework. This evaluation considers and compares the likely contribution to the value of the network of the last four to six stops for four routes that terminate in residential areas. Routes 2, 6, 8 and 11 all originate in different areas of Hamilton as shown in figure 8.2 and were chosen to demonstrate how the economic, social and accessibility impacts of a service change and the resultant trade-offs may be addressed.

Figure 8.2 Hamilton public transport case study routes



In the absence of a fully integrated ticketing system, this case study also shows how an appraisal can be performed using tag-on ticketing data without the benefit of unique IDs being available to isolate bus users from the ticketing data. The evaluation also considers the value of additional trips enabled using the Ministry of Transport National Household Travel Survey which indicates that 1.73 public transport trips per person per day are undertaken in Hamilton. This provides a possible proxy of the number of additional trips elsewhere on the network that may be affected and could be considered when reviewing the addition or removal of feeder services.

The ticketing data for this region does not contain any geo-reference data so a manual approach has been applied drawing on stop information provided on the BUSIT website and Google Maps. The value to the network of these end of services is shown in table 8.4. All evaluations included the value of the enabled trips (network effect) with resulting BCRs of between 0.5 and 2.6.

The full value of this assessment becomes more evident when the social and accessibility impacts of each service area are assessed alongside the economic evaluation (see section 9.5). By considering the trade-off between the economic value of each service and the social impacts, a more comprehensive approach can be taken to inform network planning decisions.

Table 8.4 Example of BCR calculation for spatial service change including enabled trips

Including additional enabled trips		BCR	Additional route length (km)	Average trip length (km)	Existing pax on service	Existing peak pax	New pax on subject service	Rate of growth	Proposed user charge	PV funding gap
Route2	Off peak	2.6	0.85	7.86	162,240	103,680	10,870	0%	$1.63	-$74,765
Route 6	Off peak	1	1.2	7.86	105,600	64,640	5,312	0%	$1.63	$166,628
Route 8	Off peak	1.7	1.2	7.86	114,880	61,120	12,176	0%	$1.63	$155,984
Route 11	Off peak	0.5	1.29	7.86	63,360	37,440	2,572	0%	$1.63	$246,988

9 Accessibility and social/demographic evaluation

In addition to the economic assessment of a change in public transport service or coverage, this research has sought to provide a mechanism for assessing and recognising other factors that contribute to the value of public transport. This section considers how some of the less tangible elements can be assessed and how their contribution to an individual service and the network as a whole can be measured and incorporated into network planning decisions.

9.1 Walkability

The distance a person is willing to walk is very much up to the individual and depends on a number of factors, including the topography, perceived safety and quality of pedestrian facilities. For this reason, it is not easy to prescribe how a change in accessibility to a bus stop will change a person's propensity to use a public transport network.

Walkability research is particularly helpful to understand the attractiveness of the underlying walking facilities. The terms 'walkability' and 'walkable' are common in the fields of engineering, planning and health, due to the widely recognised benefits for the social, health and economic well-being of a society. The NZ Transport Agency (2009) *Pedestrian planning and design guide*, defines 'walkability' as 'the extent to which the built environment is walking friendly' which provides 'useful way to assess the characteristics of an area or a route'. It is recognised that walkability is a subjective field of study.

Walkability tools research – variables collection methodology (Abley 2006) and *NZ Transport Agency research report 452* 'Predicting walkability' (Abley et al 2011) develop a methodology for assessing and quantifying the quality of a pedestrian environment. This has been developed further in *Street condition survey methodology'* (Fleming 2016) to accommodate the requirements of mobility impaired users.

A community street review (CSR) using Abley et al's (2010) *Guide to undertaking community street reviews* can also be used to provide a measure of the quality of the walk environment. The CSR methodology provides a standard tool for measuring walkability in New Zealand and assesses the walkability of a route from the point of view of the people using the route. It focuses on pedestrians' perceptions regarding the road or road-crossing environment, and how they feel when walking. It collects data on safety, the functionality of the pedestrian space, the ease of road crossings, the effects of urban design, and other relevant factors. The website www.levelofservice.com provides guidance and resources for undertaking CSRs and a more detailed approach to walkability assessment.

The two key variables included in the assessment to give an overview of the walkability of a review area being assessed, are gradient and pedestrian environment. The gradient of the footpath provides a good measure of the area's general topography. The gradient of both the footpath and the road must be less than 8.5% to be considered passable for pedestrians with mobility impairments (Fleming 2016). The concept of pedestrian environment encapsulates the quality of footpath design, condition of the footpath surface as well the extent of hazards, lighting, perceived safety, presence of tactile pavers and attractiveness.

An assessment of the quality of the cycle environment could also be considered in a similar fashion to the walk environment assessment proposed by Abley and Turner (2011), which may provide a useful indicator to determine the likelihood of a switch to cycling as an access mode to public transport in the affected location. It is, however, considered that cycling has a relatively minor role as an access mode compared with walking. Wedderburn (2013) also provides a useful resource for understanding the integration of cycling to access public transport.

9.2 Change in accessibility

A spatial change in service provision alters the route catchment area and may change the walk distance to access public transport for many households. GIS can provide spatial analysis and maps to measure this impact, and is the recommended approach. A high-level assessment can, however, be performed in the absence of GIS using Google Maps or similar online resources, as outlined in appendix B. GIS has been used in the Auckland case study evaluation, and for the Waikato case study, the Google Maps approach has been applied.

NZ Transport Agency (2009) prescribes the use of 1.5m per second (5.40km/h) as the mean walk speed for the vast majority of fit, healthy adults. Aged pedestrians or those with mobility impairments generally travel more slowly at around 1.2m per second (4.30km/h). Walk speed varies based on:

- pedestrian characteristics such as age, gender and physical condition
- trip characteristics such as walking purpose, route familiarity, trip length and encumbrances
- route characteristics such as width, gradient, surfacing, shelter, attractiveness, pedestrian density and crossing delays
- environmental characteristics such as weather conditions (NZ Transport Agency 2009).

Based on an appropriate 85th percentile walk access time to public transport (Wedderburn 2013), a 10-minute walk catchment is used in each of the case studies and equates to approximately an 800m access trip length.

It is important to take care in establishing the number of households that have their access to public transport affected by a service change, as access to public transport influences the decision to use public transport or complete the trip at all. A change in spatial coverage assessment requires defining the 800m catchment area around the public transport service under review. The meshblocks still within 800m of any remaining services are then removed, leaving an area that is greater than 800m from a public transport service, and become the catchment with reduced access to public transport as a result of the change.

In the spatial analysis supporting both case studies, the bus stops isolated were eliminated for all services. The case study areas were carefully chosen so the stops selected for analysis generally impacted on only one service, providing the ability to isolate and illustrate their value to the catchment area. The existing average walk distance to a bus stop in the Auckland study area is 403m but this would increase to 916m if the last 11 stops were removed.

9.3 Mode shift

There is no ‘one size fits all’ approach to determine a likely change in mode as a result of or change in accessibility. Individual decisions will be informed by individuals and their perceptions, as well as the specific location and local environments. A strict framework would therefore not be appropriate, but there are a number of things that transport planners can use as a guide to inform the likely change in mode share due to a change in walk access time to the public transport network.

Establishing the impact of the change in walk access time can be informed by previous research including Wedderburn (2013) which provides elasticity values to understand the relationship between public transport patronage levels and changes in the access trip leg walk and cycle time summarised in table 9.1.

From this it is anticipated for every 1% increase in walk access time, the demand for public transport will decrease by 0.35% during peak periods and 0.32% outside peak periods.

Table 9.1 Elasticities for public transport demand with regards to walk and cycle time (Wedderburn 2013)

Access/egress mode	Peak	Off peak
Walk	-0.35	-0.32
Bicycle	-0.35	-0.16

These elasticities could be applied to table 7.6 to predict the likely reduction in public transport use for the meshblocks examined in the case study area. The limitation with this is that it would only be useful if the number of actual public transport users was known for each meshblock. If a regional council knows either the number or the percentage of public transport mode share for the meshblock, this methodology could be applied. For example, Meshblock MB712121 contains 222 households and if all of these households were public transport users, applying the change in walk access elasticities in table 9.1 would imply a 17% reduction in public transport use in the peak period and a 15% reduction in off peak.

Stated preference surveys are likely to provide the most representative source to understand the probable change in mode choice and travel behaviour arising from a specific change in public transport service provision. To determine the likely impact, a stated preference survey can be conducted with existing and potential public transport users in the catchment area. Answers to carefully constructed questions provide a valuable understanding of how respondents daily travel patterns and travel choices may change as a result of a change in service provision. This is the recommended approach to develop an understanding of the likely travel behaviour of the residents and public transport users in an isolated area under review.

An example of this is a study by Delbosc et al (2015), who undertook stated preference surveys in their study of travel mode choice in a 'greenfields' development in Melbourne. In the absence of a bus service, users were asked how they would make their trip. Survey results indicated the following changes in travel behaviour:

- 26% would get a lift with someone
- 20% would not make this kind of trip
- 20% would walk
- 18% would drive a car
- 11% other
- 4% would not have travelled
- 2% would cycle.

In the absence of a stated preference survey the results summarised by Delbosc et al (2015) may provide indicative default values with approximately 44% switching to private vehicle travel (as a driver or passenger), 22% switching to active modes and the remainder making other arrangements or not travelling. These default values coupled with consideration of the relative attractiveness of other nearby public transport services on the network could be used to address the likely behaviour change.

The Delbosc et al (2015) study also concluded that migrants and households with children were more likely to use the bus, while there was no significant relationship between the distance from the bus route and the frequency of use.

The Waikato case study analysis was informed in part by an origin–destination survey conducted in 2013 to calculate additional trips made on their network. Respondents of this survey indicated their likely alternative mode choice if the bus was not used. This data has been used to inform the mode switch factor in the SP10 analysis for the Waikato case studies.

The proposed national integrated ticketing system that captures both the boarding and alighting location would alleviate the need for an origin–destination survey. It would also provide a high level of consistency in ticketing data across regions, adding a further level of constancy from which comparisons and ranking of funding assessments can be made. It is understood the nationwide ticketing initiative is planned for implementation in 2019.

In the absence of any stated preference survey data, or accurate numbers of public transport users at a meshblock level, an assumption (in the SP10 evaluation) has been made that the proportion of households further than 800m from a bus service following the spatial service review will switch to other modes, or choose not to perform the trip. For the temporal example, an assumption has been made that 50% of trips will transfer to other modes or not occur. A change in temporal coverage impacts on users over the full length of the route, and given that portions of the route would continue to have access to other services that ran after 7pm, it is difficult to determine change in access without the benefit of results from a stated preference survey.

The Total Mobility Scheme, funded in partnership by local and central government, provides subsidised taxi services to people with serious mobility constraints that prevent them from assessing and using public transport (NZ Transport Agency 2016a). An increase in access distance to public transport as a result of a service provision change may force some vulnerable users to switch to Total Mobility. This would mean an increase in user cost for the passenger and a transfer of government subsidy. It may, however, be more efficient to withdraw a very poorly utilised end of service, and subsidise a few additional Total Mobility trips, than run a schedule of poorly patronised large public transport vehicles.

The research recommends stated preference surveying is the most effective mechanism to understand the likely magnitude of mode switch when considering a change in public transport service provision.

9.4 Social cost of mobility

The use of the term 'transport disadvantaged' refers to groups who may have poor mobility and are thought likely to be at higher risk of social exclusion and reduced quality of life as a result. Public transport service provision plays an important role in minimising the social cost and risk associated with poor accessibility to transport for vulnerable sectors of the community (Stanley et al 2011).

Stanley et al (2011) examine the value of mobility and social exclusion focusing on the willingness to pay for increased mobility as measured by trip activity, and concludes there is a positive correlation with higher household income, connection with the community, number of trips per day, level of personal growth, and a lower risk of social exclusion. Using the statistically significant relationships established by Stanley et al (2011) between household income, trip rates and risk of social exclusion, the value of an additional trip can be estimated at approximately A$20 per trip. This value is not mode specific, and is estimated to decline with increasing household income.

To provide some context, when the A$20 trip value was derived in 2011, the Australian study area had an average annual household income of A$69,426. The median annual income in the Mission Heights study area is in the range of NZ$80,000 to $100,000 which is approximately 30% higher than that specified in Stanley et al (2011). This suggests the value of an additional trip in the Mission Heights study area would be lower than A$20 per trip. Stanley et al (2011) provide guidance that if income were to double, the marginal value of consumption to individuals would be approximately halved.

The social cost of mobility and social inclusion topic is a sensitive topic. In North America there is an emerging trend that public transport authorities are moving away from assigning economic values to specific classes of people (for example the economic value of the trip or cost–benefit to seniors, people with disabilities, low income populations); this is now often handled through a multiple accounts evaluation (MAE) approach (Crown Corporations Secretariat 1993) or multi-criteria assessment.

The MAE approach compares portions of the population served or not served by specific public transport proposals, with the evaluation being performed through a scoring and weighting scheme that incorporates a range of agreed criteria relevant to the project or service. This method avoids the need to debate how to score or assign a dollar figure for various classes of people. The main concern about MAE is the subjective development and application of the weighting system (Wallis et al 2013). An equal weighting can be imposed, leaving decision makers to consider the range of views on the relative importance of each criteria. This is a similar method to applying a LoS framework approach which is commonly applied in the traffic engineering discipline to provide measures of midblock and intersection congestion and performance.

The research team developed a similar classification system to represent the relative impact of the social aspects of changes in mobility and demonstrated the application of it in the case study examples in the following section and this is the recommended approach. This approach may be particularly helpful to public transport planners and generally aligns with the Canadian MAE approach.

To develop and implement a set of LoS type social impact indicators we propose the compilation of a list of components that can be enumerated, based on demographic and walkability aspects of the spatial assessment. This will enable public transport planners to take into consideration the individual components within their unique environments and manage any trade-off in terms of social effects against an economic analysis without prescribing what weightings should be applied to each. Subsequently, the planners can consider what LoS performance is acceptable based on the community and political sensitivity of the changes in service provision being assessed.

The Austroads pedestrian facility selection tool by Abley et al (2015) provides an example of a similar tool that has been developed. This tool provides LoS measures for perceived delay, safety and walkability alongside an economic evaluation of the benefits of various crossing treatments. It does not address trade-offs, instead favouring providing the necessary information to practitioners, which enables them to take a considered approach. As is evident in the example provided in figure 9.1 the treatment with the best BCR results in poor LoS performance; however, other options with lower measures of economic efficiency produce better LoS outcomes. The decision as to which treatment should be carried forward is left up to practitioners based on the information provided by the tool.

Facility assessment

	Suitable for site?	Pedestrian delay	Vehicle delay	Predicted crash rate	CSD	ASD	SISD
No facility		55 sec	0 sec	0.05 /year	204 m	73 m	127 m
Platform	No						
Kerb extensions	Yes	44 sec	0 sec	0.03 /year	188 m	73 m	127 m
Median refuge	Yes	12 sec	0 sec	0.04 /year	78 m	73 m	127 m
Kerb extensions and median refuge	Yes	11 sec	0 sec	0.03 /year	69 m	73 m	127 m

	Perceived delay	Perceived safety	Pedestrian LOS	Pedestrian delay cost	Pedestrian delay saving	Vehicle delay cost	Crash cost	Safety saving	Total benefits	BCR
No facility	E	F	F	$ 101,000			$ 199,000			
Platform										
Kerb extensions	E	F	E	$ 81,000	$ 21,000	$ 0	$ 129,000	$ 70,000	$ 90,000	5.0
Median refuge	B	C	C	$ 22,000	$ 79,000	$ 0	$ 169,000	$ 30,000	$ 109,000	3.5
Kerb extensions and median refuge	B	C	C	$ 20,000	$ 82,000	$ 0	$ 139,000	$ 60,000	$ 141,000	3.0

Figure 9.1 Example of Austroads pedestrian facility assessment tool

9.5 Social and accessibility case study evaluation

The social and accessibility evaluation builds a profile of the study area considering social, demographic and accessibility elements and the likely level of impact a change in service provision may have. Arbitrary low, medium and high levels have been ascertained for each variable to assess each component. The thresholds will likely be different for different regions and environments, so the parameters should be tested for suitability by the practitioner based on the perceived needs of the local area. The case studies from chapters 8 and 9 are revisited to illustrate how the value of these less tangible elements may be considered.

9.5.1 Case study one – Auckland

The recommended economic assessment considering the value of both the enabled trips and adjusted trip length is brought forward from table 8.2 and a social and demographic evaluation of the Mission Heights study area is taken from analysis in chapter 8 and shown in figure 9.2. This demonstrates the level of the impact of public transport service availability on this component of the public transport network is relatively low in terms of level of deprivation and income; however, there is a high impact on the number of households affected by the change in service coverage.

A separate temporal analysis is not required as apart from the Mission Heights study area, all parts of the route 500 service double up with other services, so the social impacts are likely to be similar to that of the spatial evaluation as presented in figure 9.2.

9.5.2 Case study two – Waikato

The social and accessibility evaluation for each of the different areas compared in Waikato has been developed and shown in figure 9.3. This evaluates each route using the economic assessment capturing all enabled trips and provides a good overview of the different levels of impact public transport service coverage has on the community it services. There is a high impact in terms of level of deprivation and income; however, there is a low impact as the number of households without an alternative service within 800m is very low. Routes 6 and 11 are the least efficient as they have BCRs of one or less; however, the social impacts are greater on route 11 as there is a higher deprivation score, lower household income and fewer vehicles available to each household. Both areas are relatively well serviced by other routes as there are few or no households greater than 800m walk from other bus services. Hamilton's current public transport network has extensive coverage, so there are very few households that would not have good access to several services.

The practitioner should consider the trade-offs between the economic evaluation and the social impacts to enable a balanced and well-informed decision when considering a change in service provision.

Figures 9. 2 and 9.3 demonstrate an early concept for a spreadsheet tool to bring together the economic and social/demographic aspects of an evaluation. It demonstrates a more comprehensive approach to assessing isolated services and their value to the community and public transport network as a whole. The corresponding spreadsheet is submitted with this report to support the research.

Figure 9.2 Social and demographic evaluation for Mission Heights Auckland (case study 1)

		Mission Heights - Auckland			
		Option 4 recommended from Chapter 9	BCR		
Economic Assessment		**Adjusted trip length & enabled trips**	**Low**	**Medium**	**High**
	BCR	6.4	<2	2-4	>4
	PV Funding Gap	-$965,414			
	Passengers on subject service (per annum)	201935			
	Average trip length	13.88			
			Level of Impact		
Social/Demographic Evaluation		From data analysed in Chapter 8	**Low**	**Medium**	**High**
	# Households in 10 min walk catchment	2148			
	Median Deprivation Score	3	1-3	4-7	8-10
	Median Household Income	105265	$90,001 +	$60 -$90,000	$0 - $59,999
	Average number of Vehicles per HH	2.28	2+	1-2	0-1
	Age profiles of affected (% of Less than 20 yrs and 65+)	36.6%	< 25%	26-49%	50% +
			Level of Impact		
Accessibility Evaluation			**Low**	**Medium**	**High**
	# of households > 800m from similar PT service	1224	< 50 HH	< 200 HH	200+ HH
	Gradient	7-8%	<7%	7-8%	>8%
	Pedestrian Environment	Above average	Above average	Average	Below average

Please note the level of impact ranges have been arbitrarily set to demonstrate a possible assessment of each component. It is recommended the thresholds be set and tested for suitability by practitioners based on the perceived needs of the local area.

Figure 9.3 Social and demographic evaluation for Waikato routes assessed (case study 2)

		Waikato							
	Options	Including enabled trips - Off peak only					BCR		
Economic Assessment		Route 2	Route 6	Route 8	Route 11		Low	Medium	High
	BCR	2.6	1	1.7	0.5		<2	2-4	>4
	PV Funding Gap	-$74,765	$166,628	$155,984	$246,988				
	Passengers on subject service (per annum)	10870	5312	12176	2572				
	Average trip length	7.86	7.86	7.86	7.86				
							Level of Impact		
Social/Demographic Evaluation							Low	Medium	High
	# Households in 10 min walk catchment	1181	1715	2442	2640				
	Median Deprivation Score	8	6	9	9		1-3	4-7	8-10
	Median Household Income	$55,000	$52,500	$56,700	$22,500		$90,001 +	$60 -$90,000	$0 - $59,999
	Average number of Vehicles per HH	1.6	1.7	1.6	1.46		2+	1-2	0-1
	Age profiles of affected (% of Less than 20 yrs and 65+)	47.0%	43.0%	42.0%	46.0%		< 25%	26-49%	50% +
							Level of Impact		
Accessibility Evaluation							Low	Medium	High
	# of households > 800m from similar PT service	13	1	13	0		< 50 HH	50-200 HH	200+ HH
	Gradient	<7%	<7%	7-8%	<7%		<7%	7-8%	>8%
	Pedestrian Environment	Average	Average	Average	Average		Above average	Average	Below average

Please note the level of impact ranges have been arbitrarily set to demonstrate a possible assessment of each component. It is recommended the thresholds be set and tested for suitability by practitioners based on the perceived needs of the local area.

9.6 Other considerations

9.6.1 Application to service changes in commercial/industrial areas

The case studies presented in sections 8.3 and 8.4 demonstrate a methodology for assessing the value to the network of a spatial or temporal service change using available datasets and an adapted version of the EEM simplified procedures. While this methodology has been illustrated using areas that are predominantly residential, the same principles would be applicable to the assessment of a service coverage change in a commercial or industrial area with a high number of employment locations (and can be informed by census data). The assessment would consider and measure the impact based on the accessibility of jobs and the demand for public transport trips in the area.

From an economic perspective it would not be any different from the case studies presented. The key input to the evaluation would be determining the future demand for public transport trips by employees in the area being evaluated during the peak periods. There would be less impact on the social aspects and value of accessibility to the transport vulnerable, as they are less likely to need to travel to commercial/ industrial locations.

9.6.2 Short and long-term effects

The short-term effects or direct impact of a change in service provision (such as a change in patronage levels) are those that are evident shortly after the change is implemented. The long-term effects are realised when the system reaches a 'steady state' following the changes and may only be evident a year or longer after a change occurred (Balcombe et al 2004).

There is a significant challenge to isolate and measure the long-term effects of changes in network provision or network value. This is due to the sensitivity of the public transport environment to a number of factors that can have both a direct and an indirect influence on demand over a long run. Isolating the change afforded to one individual factor in terms of direct effect and value is aspirational and in most instances likely to be unattainable. Some of the exogenous factors that are likely to have influenced demand over time, making isolating long-term effects of a specific change very difficult include:

- fuel prices
- car ownership levels
- employment rates
- infrastructure or road design changes
- additional network changes
- operational changes
- fare changes
- population growth
- corridor capacities
- changes in land use activity that may influence public transport demand (for example residential subdivision, commercial centre expansion, service centre development or changes in school locations).

9.6.3 Road safety benefits

The benefits of public transport resulting from reduced traffic crashes are noted by many sources (Litman 2010; ECONorthwest et al 2002) although public transport projects are unlikely to be undertaken with the main objective being to reduce or mitigate traffic hazards. An assessment of the value of a component of the network using the EEM procedures considers road safety implicitly within the road traffic reduction benefits so there is no need to consider this further.

9.6.4 Environmental benefits

The primary environmental benefits of public transport come from reductions in congestion, noise and air pollution as a result of a reduction in private vehicles.

Environmental benefits, however, are sensitive to the travel conditions, load factors and the types of public transport vehicles being used on the component of the network being assessed. During peak periods when load factors are high, buses provide an energy efficient mode; however, on services or off-peak periods when buses have very low load factors, or are empty, the environmental benefits may be negative. The research has not attempted to enumerate environmental benefits for the case study examples over and above the environmental benefits contained within the road traffic reduction factors (peak period).

9.6.5 Health benefits

The main health benefits come from facilitating access to healthcare; however, these health benefits tend to be less tangible as they are difficult to measure and as a result can often be undervalued. Sedentary lifestyles can also be a substantial health risk, therefore increasing the physical activity of otherwise sedentary people through increased public transport use and public transport oriented development may provide significant health benefits (Litman 2015a).

Any mode shift towards active travel would produce health benefits through the EEM process, but are not considered within the SP10 procedures to evaluate improvements to existing public transport services. Any significant mode switch to active transport would require separate calculation of the health benefits.

9.6.6 Risks and limitations

The areas of concern that may bias or add complexity to the evaluation process or produce a high level of noise include (but are not limited to):

- network changes, which in reality do not usually involve just one spatial or temporal change to a route in isolation but are part of a review focused on a geographical area of the network and are implemented as a suite of changes
- uncertainty as to the availability of historic GTFS feeds that correlate exactly with the network change implementation dates
- seasonal changes in patronage
- road works variability.

10 Conclusions

Public transport funding is provided by the government to deliver public transport that provides access and choice and unlocks the potential of urban areas (MoT 2015). This research explored the elements that influence the value of a public transport service and sought to determine the best methodology for appraising the value of isolated services, considering their contribution to the wider network and the economic and social value of the service to the community. The research reviewed current guidelines and has suggested a framework to better capture the travel demand across the network, and value broader public transport benefits for future benefit calculations when assessing public transport network reviews, in line with the research objectives.

The literature review and stakeholder engagement stages of the research provided insight into the value components that may be linked to temporal, spatial and other operational changes in public transport service provision. The elements that contribute or impact on the value of public transport fell into the broad categories of cost, land use, user, social, health, mobility, environment, road safety and mode shift and are summarised in table 10. 1

Table 10.1 Elements that impact on the value of public transport

Impact	Benefit/disbenefit
Cost	Change in development cost due to parking supply/demand
	Traffic enforcement variation resulting from change in traffic volume
Land use	Relationship with property value
	Land use accessibility/integration
	Accessibility, connectivity and coverage of transport network
User/social	Travel and vehicle ownership cost savings
	Social inclusion – accessibility to jobs, education and other facilities
	Community cohesion
Health	Access to healthcare
Mobility	Low cost, affordable transport option
Environmental	Pollution (air, noise) through change in private vehicle use
	Energy efficiency or resource cost Change in per capita vehicle mileage
Road safety	Improve general road safety through reduced traffic crashes
	Crash reduction through congestion relief
Mode shift	Patronage change

While some of these benefits are tangible and able to be enumerated, a number of them are less tangible and their contribution to the value of public transport at either a service or network level is not well understood. This made the task of developing a methodology for appraising and determining the additional incremental value added to the network by services such as feeder or evening services that in isolation may be comparatively inefficient, very challenging.

The following data sets provided key inputs to complete an evaluation of an isolated component of a network (spatial or temporal) using the proposed methodology.

- integrated ticketing data to understand the number of patrons affected and the distance they travel across the network by fare (as a proxy for user) type
- demographic data to understand how many households are in the affected catchment and how vulnerable they are likely to be to changes in service provision based on a deprivation index and related demographics
- accessibility analysis to determine the change in walk access to the public transport network and extent to which affected users are likely to continue to use public transport
- an assessment of the walkability of the local footpath and crossing facilities as a means of access to other nearby public transport services
- origin–destination survey, stated preference survey or the adoption of default values to estimate the rate of uptake of other modes or likelihood of changing travel plans (including not making the trip).

The economic evaluation framework provides the foundation for completing an economic assessment of a component of a public transport network, but would require modifications to consider enabled trips (network effect), trip length and mode switch.

The value of the integration of public transport services and the spatial and temporal connectivity of a public transport network are key to a passenger's decision to use public transport and this network effect delivers greater value than each service in isolation. The benefit of this effect was captured through analysing integrated ticketing data to understand where users from a specific area travelled, and what additional trips were enabled as a result of access to public transport from a residential area. Some modifications to the simplified procedures are suggested to value these additional trips and to adjust average trip distance to accurately reflect the average trip length observed from ticketing data. Alternatively, these modifications could be introduced through the application of full procedures.

The unavailability of a transport service for the 'first mile' or 'last-mile' is acknowledged as one of the main deterrents to the uptake of public transport, in particular, for the group known as the 'transport disadvantaged', predominantly children, the elderly and the disabled. Ease of walkability and walk access to complete the first and last mile of a journey influences public transport demand and therefore the value of a service. Walkability and the social and demographic make-up of a community was evaluated using available census data, and a LoS type approach applied the value accessibility. The effect of change in accessibility was also considered in the economic assessment through the likely change in mode share resulting from a change in accessibility to public transport.

The mobility benefits enabled by public transport can be classified as user benefits, equity benefits, public service support and option value (Litman 2015a). Direct users of public transport benefit from increased access to services, social and recreational activities. It can improve access for people to education and jobs which in turn can improve people's economic opportunities. These benefits were found to be challenging to enumerate. During discussions suggestions were made as to how these benefits could be accounted for during a review.

The outcome of the research is the presentation of a framework (with case study examples) which provides practitioners with the information they require to consider the economic and social implications of a change in service provision that would otherwise be perceived as demonstrating very little value. The framework presented in this research presents a more integrated network approach to support investment decisions by modifying the EEM simplified procedures to account for the additional contribution to the network of a network service or component of the network, and alongside this consideration is given to the social value of a change in public service travel provision. The research team has not, however, tied the value of the social and accessibility element into an economic evaluation framework. It is recommended the decision lies with the public transport planner as to how the social, accessibility elements and many trade-offs are managed, taking into consideration individual community and political sensitivities.

For the two case studies an Excel spreadsheet is provided in appendix E, located at www.nzta.govt.nz/resources/research/reports/616. This demonstrates the application of both the economic, and social and demographic assessment methodology and provides the foundation to develop an assessment tool for practitioners. The aim is to develop a tool that closely aligns with, and complements existing economic evaluation tools provided by the Transport Agency. The tool will be available for the industry to aid in the assessment of public transport service reviews in the future.

10.1 Further considerations

A number of considerations towards the application of this research follow:

1. Additional guidance towards the application of the EEM procedures may be helpful to assist practitioners with public transport reviews. This guidance should acknowledge the appropriate methodology for recognising the value of additional enabled trips on the network and provide a mechanism for adjusting trip distance within the EEM economic evaluation procedures. This should also recognise that not all route changes are focused on achieving the same per route value; a route instituted to provide coverage would have a different value to one solely reflecting passenger demand or a route that contributes a first/last mile purpose.
2. There may be value in developing a user guide for the EEM simplified procedures templates to assist practitioners in understanding each component of the evaluation process and be easily able to use the spreadsheets to aid decision making as well as inform funding applications.
3. Caution should be applied in evaluating specific network components too precisely. A level of professional and situational judgement to valuing less tangible elements of public transport is recommended.
4. The role of the Ministry of Education school services should be considered, more specifically how they contribute and impact on the value of other services and the public transport network as a whole.
5. The impending nationwide integrated ticketing system has the ability to support the data requirements of the Transport Agency's economic evaluation procedures. Key considerations in the development of this system include providing transparency to understand trip distances through geo-referencing, trips traceable by unique card ID, and the availability of one dataset that is wholly accessible to practitioners.

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Appendix A: International literature

Literature related to public transport network planning generally falls into either qualitative or quantitative studies. The qualitative studies include generalised state-of-the-practice publications and journal articles by both academics and practitioners that could be considered 'personal perspective' or 'opinion' articles. In contrast, the quantitative studies are typically peer-reviewed articles written by academics as evidence-based studies following an analytic approach or as network (mathematical) programming research studies.

A1 Case study publication and research review

The publications reviewed are categorised into three subsets:

- Qualitative: perspective or opinion articles
  - Papers and journal articles that promote a point of view of the benefit of the network effect or effect of feeder bus networks on overall public transport networks. These papers may cite system level or regional demographic data to support their research hypothesis, but there is little analysis at the route or subsystem level to support the conclusions.
- Qualitative: best practice publications for practitioners
  - Papers and publications that serve as best practice guides for the implementation of specific service planning and delivery concepts. These industry papers may cite general or specific case study evidence applicable to specific contexts, including best practice implementation approaches, but these publications do not include analysis of outcomes. Consequently, data reported tends to be high-level system performance. As many of these studies are published in the United States, there is significant reliance on the National Transit Database which provides a wealth of public transport operating and performance data, but the types of data collected limit analyses to the system and modal levels and not to subsystems within modes.
- Quantitative research
  - These papers are analytical or mathematical/programming studies of specific public transport problems. The most common problems relevant to this research are described as the 'transit route network design problem' (TRNDP) or the 'feeder bus network design problem' (FBNDP). Within this class of studies, there is an understood process of planning, designing and delivering public transport, generally described in five steps:
    - design of routes – guided by passenger flows
    - setting frequencies – responding to travel demand (volume)
    - developing timetables – setting detailed travel times and hours of service
    - scheduling buses – allocating fleet to the timetables
    - scheduling drivers – scheduling labour within the required operational rules.
  - The quantitative body of research also recognises five system planning approaches employed by public transport operators (the quantitative body of research largely focuses on the last of these system approaches):
    - manual
    - market analysis

- systems analysis
- systems analysis with interactive graphics (eg GIS)
- mathematical optimisation approaches.

A summary of the publications reviewed is provided in the remaining sections of this appendix.

TCRP-95 Chapter 10: Bus routing and coverage

Section: Traveller response to transportation system changes (Transit Cooperative Research Program et al 2003)

Study type: Qualitative: Best practice publications for practitioners

This guide for practitioners is descriptive in nature, but one section is particularly relevant to this study. Although it does not provide useful statistical data, it does illustrate limitations in the use of reported public transport data in the United States.

Unlinked trips are the mandated measure for reporting transit ridership to the Federal Transit Administration and its National Transit Database. An unlinked trip is a passenger trip made in a single public transport vehicle. A count of unlinked trips is effectively the same as a count of passenger boardings. A one-way trip from home to work that involves one transfer, such as between two buses or a bus and train, produces two unlinked public transport trips. Yet, those two unlinked public transport trips serve only one person trip from the rider's perspective, have the social and environmental benefit of only one public transport trip, and often generate only one public transport fare.

This measure complicates the analysis in any situation where public transport routing changes increase or decrease the need for passengers to transfer. To fully understand whether routing changes have attracted more (or less) ridership, the before and after number of 'linked trips' must be determined. A linked trip is the entire person trip between a rider's point of origin and destination, irrespective of how many vehicles or modes are used. The one-way trip from home to work used as an example above is a single linked trip. Since linked trips are not the official reporting measure, they are not often surveyed or estimated, and the meaningfulness of route structure change evaluations suffers accordingly. More unlinked trips may reflect nothing more than the effect of more forced transfers.

In short, nationally-reported data from the United States across different system types, even when compared over time through cycles of service changes, is inadequate to answer the questions of this research study, given they do not adequately account for transfers that occur between routes and modes.

Public transport network planning in Australia: Assessing current practice in Australia's five largest cities (Mees and Dodson 2011)

Study type: Qualitative: Perspective or opinion articles

Prior research by the authors identified two alternative strategies that are typically found in dispersed North American or Australian cities. The first was described as a 'radial' strategy in which services are overwhelmingly focused on serving radial trips from suburbs to the city centre, oriented to achieving single-seat journeys (Thompson and Madoff 2003). This strategy supports few non-radial trips and is poorly suited to meeting the multi-directional, multi-destination travel demand found in dispersed cities. The second strategy was described as a 'ubiquitous' or 'dispersed' network strategy in which public transport lines serve a diverse array of multi-directional trips beyond those catered to by radial services (Mees 2000) (Nielsen et al 2005). Such a strategy depends on transfers between services to enable diverse journeys beyond those catered to by radial lines.

Mees and Dodson (2011) focus on institutional frameworks for the planning and delivery of coordinated public transport services. They describe the Vancouver public transport system as having the closest approximation within the North American context to the characteristics of the German Verkehrsverbund planning and delivery model, which they suggest as the idealised public transport framework. They then focus on the deficiencies in the five Australian case studies presented in this paper, emphasising the historically weak integration of their rail and bus networks. Mees and Dodson (2011) suggest poor integration of modes in Australian cities is in part due to the failure of policy makers and planners to overcome the legacy of institutional fragmentation that has marred the history of urban public transport planning. Case studies included in this study are Sydney, Melbourne, Adelaide, Perth, and Brisbane.

Case study: Sydney

Sydney has by far the highest public transport usage rates and mode shares of Australia's cities. However, these high utilisation rates are largely a product of Sydney's well-patronised rail network, which has maintained its share of work trips for more than three decades. Most workers employed in Sydney's central business district (CBD) travel by public transport: around 46% use trains, 22% buses and ferries, 7% walk or cycle and just 19% travel by car. While rail is a strong performer in Sydney, it does not link well with other forms of public transport; 47% of train passengers walked to the station, 35% came by car and only 16% used buses.

Case study: Melbourne

Public transport in Melbourne accounts for a substantial majority of work trips to the CBD. Some 61% of CBD workers travelled by public transport in 2006, 8% walked or cycled and 27% used cars. In contrast with Sydney, mode share for non-CBD work trips is uniformly low. Although Melbourne's trams face impediments from street traffic, service levels (frequencies and hours of operation) are high. Bus service levels are much lower than for trams, even for buses operating in the same areas that trams serve: low frequencies and limited or no evening or Sunday services is the typical pattern, especially for outer suburban bus lines, although recent years have seen some extensions of operating hours. Buses generally serve local and cross-suburban travel markets, with radial travel to the CBD mainly served by trams and trains although some bus lines ply radial routes where rail links are sparse. Inter-modal travel rates are lower than in Sydney, with only 10% of rail passengers using feeder buses or trams to access the station.

Case study: Adelaide

During the 1970s, Adelaide was the only Australian city where public transport usage rates and shares of work travel increased. By the 1981 census, Adelaide briefly surged ahead of Brisbane for mode share for travel to work. Beginning in the 1980s, concerns about rising deficits led to a reversal of some of the policies of the 1970s. Service levels were gradually reduced, especially on/off-peak, evening and weekend services. A particular feature of the period from the 1980s until around 2005 was continuing debate and uncertainty about the future of Adelaide's poorly patronised rail system, the last major system in the country that has not yet been electrified. The rail service received little capital investment, some lines were closed and service levels remained poor. Express bus services were introduced that competed with the rail system for passengers. Adelaide now has the lowest mode share for work trips, and the lowest per capita usage rates, of the cities discussed in this report. Service levels are generally low, particularly outside peak periods: for example, most rail lines operate hourly in the evening and on weekends, and most bus services provide similar service levels.

Case study: Perth

Three decades ago, Perth's public transport demand was falling. Perth's poorly patronised diesel rail system was threatened with closure, and in 1979 the line to Fremantle was shut. However, the Fremantle line was reopened, and the rail system electrified and substantially extended. The most recent round of rail expansion lifted patronage to 55 million in 2008/2009, compared with 65 million for Queensland Rail's Brisbane Citytrain services. The average resident of Perth made 34 rail trips in 2008/2009, compared with 23 for the average southeast Queensland resident (and just 10 for the average resident of Adelaide). Perth now has Australia's fastest trains, and the most frequent. On all lines, trains now run at least every 15 minutes until 7pm every day of the year, with 30-minute evening services.

Case study: Brisbane

Brisbane City is Australia's largest metropolitan authority encompassing a population of approximately 900,000 residents. Public transport in Brisbane and the wider southeast Queensland region has historically comprised a network of radial rail lines originally formed in the late-19th century to serve regional townships such as Ipswich, Beenleigh and Caboolture. This system was improved in the 1970s to offer stronger suburban connections although it was not until the last decade of the 20th century that services achieved half-hourly frequencies off-peak. In 2008/2009 the rail network achieved a patronage of 60.9 million journeys, representing one third of total public transport use in southeast Queensland. Use of public transport for the key journey to work trip declined from 30% of commuters in 1976 to just 21.2% in 2006, or about 8% of trips in 2005.

Reviewer comments

Although Mees and Dodson (2011) argue that Vancouver is the best North American example of the German Verkehrsverbund planning and delivery model, much of the paper focuses on general criticisms of the performance of five Australian case studies. Modal data reported for each of the five cities is inconsistently presented across case studies and presented only at a high level, precluding any meaningful comparison among the cities. While the paper focuses on the network benefits derived from a centralised planning and delivery model, there is no specific discussion of how the organisational structure affects network integration. In metro Vancouver, public transport carries 52 annual trips per capita, placing Vancouver last among the five largest Canadian public transport systems in this measure and significantly behind the Calgary's fourth place with 74 annual trips per capita (Singer and Burda 2015). One limitation of the study is that it focused on the performance of five public transport agencies with varying municipal and regional governance structures; part of Vancouver's lower performance is directly related to its regional focus, compared with the municipal focus of most other public transport agencies in Canada.

Network design for public transport success: Theory and examples (Nielsen and Lange 2008)

Study type: Qualitative: Best practice publications for practitioners (also elements of perspective or opinion)

The authors introduce their paper, stating that, 'the design and planning of network structure for public transport... is more or less neglected in standard texts on public transport or transport policy'. Good practice in public transport planning and delivery seems to have four interrelated factors in common (Colin Buchanan and Partners 2003). These are:

- Regional organisation – the existence of some kind of regional structure is the element that many authors have argued as essential.
- Funding – a willingness to commit funds to both operations and infrastructure by relevant stakeholders is a pre-requisite and by itself would appear to be able to generate public transport patronage, but not modal shift from car.

- Supporting policy – complementary policies that reinforce the underlying transport policies in their achievement of modal shift.
- Land use and transport co-ordination – successful coordination between land-use policies and transport policies in recognition of their conjoint spatial attributes.

In order to succeed in the market competition with the motorcar, much of the resources of the public transport system must be directed towards the main transport corridors. The concentration of resources in a region however must be balanced with the need to provide a minimum transport service to all citizens irrespective of car availability, physical abilities and area of residence. The development of a strong, attractive travel network open to all members of the public and designed for universal accessibility will reduce the need for special, tailor-made solutions. Too extensive use of special services may divert resources from the task of creating a basic, high-quality public system.

The authors cite Mees' (2000) description of 'Squaresville' as an ideal network scenario with real world comparisons between Melbourne and Toronto. In citing Mees, some of the fundamental errors in describing the Toronto context were carried forward, starting with the notion that Toronto's 3.9 million population in 1990 is comparable to that of Melbourne's 3.0 million. Mees concludes that Toronto's high quality of bus services in the suburbs and their excellent integration with rail in Toronto contrasts with the poor bus service and lack of integration with rail in Melbourne. Mees' fundamental error in the Toronto case study is in his exclusive focus on the city's public transport network, compared with that of regional Melbourne while dismissing the effect of differences in urban and regional governance structure.

In practice, public transport works by concentrating passengers into selected corridors, and inevitably this leaves some journeys without a direct connection. Transfer is an inescapable feature when it comes to providing comprehensive linkages within an urban area. Furthermore, there is a range of public transport modes, each of which offers a different combination of characteristics such as speed, capacity, ride quality, ability to penetrate different types of areas and cost. Letting different modes and types of lines (eg express and local services) play different roles in the total network is an important way of getting value for money in public transport. It can also be highly advantageous for passengers to substitute a fast mode (such as rail) for part of their journey, instead of a slow mode (such as bus). Indeed, only by doing so will public transport offer an acceptable alternative to the private car for longer journeys (Nielsen and Lange 2008).

Reviewer comments

Toronto is a large city, both in its geography and population; its current population exceeds 2.6 million in a region with over 6.5 million. As a relatively old city, by North American standards, and like other North American cities founded in the 17th and 18th centuries, Toronto has a large and relatively dense urban core. Toronto's total central business district employment is over 482,000 (Toronto City Planning 2014) and the density of its urban core exceeds 400 jobs and residents per hectare. At the city-wide scale, Toronto's density is just over 50 jobs/residents per hectare, and there are a number of major urban centres within the city outside of the downtown core. This concentration in the CBD and high density at the city-wide scale, coupled with a relatively barrier-free topography, provides a framework for the Toronto Transit Commission to operate a grid of high-frequency bus routes along both north-south and east-west arterials. In short, Toronto's street network supports Mees' 'Squaresville' example, but its relatively high urban density at the city-wide scale supports high levels of ridership on bus routes throughout the urban grid. Mees dismisses the relationship between urban form and the effectiveness of the public transport network, but Toronto's urban form is widely understood to be central to the success of its public transport network.

Mees dismisses urban form and regional structure as irrelevant to Toronto's outcome while basing his regional comparisons on the practices and performance of the Toronto Transit Commission (TTC), an entity that can be described as equivalent to a council-controlled organisation of the City of Toronto. Two local governance structures are in place in the Greater Toronto – Hamilton Area (GTHA); Toronto and Hamilton are amalgamated unitary authorities, while remaining municipalities in the GTHA are overlapping upper tier municipalities (regions and formerly counties) or lower-tier municipalities (cities). Local public transport may be operated by either level of government; in Durham and York regions (east and north, respectively), public transport is provided by the upper-tier municipalities (regions), while in the region of Peel to the west, local public transport is provided by the lower-tier municipalities (cities) of Mississauga and Brampton. To illustrate the scale of cities in the GTHA, the Toronto's CBD is located 30km from that of neighbouring Mississauga (the second largest municipality in the region with nearly one million in population), while Markham in neighbouring York region is also 30km from the Toronto CBD. In contrast, the Hamilton CBD is located 70km from the Toronto CBD, while the extra-regional city of Kitchener is 110km from the Toronto CBD. Consider that Auckland's CBD is approximately 30km from Papakura and 110km from the northern edge of Hamilton.

At the broader regional level, commuter rail and regional bus services are provided by GO Transit, an operating division of Metrolinx, itself a regional planning and project delivery agency of Ontario's provincial government. All the cities mentioned above are served by the GO Transit regional bus (56,000 weekday boardings) and rail (271,000 weekday boardings) network, and nearly all local bus systems within the GTHA provide a route interface and discounted fare for transfers between the regional GO Transit system which primarily serves radial services between outlying regions and Toronto's CBD at Union Station (VIA Rail Canada also offers commuter passes on the Quebec–Windsor corridor serving Union Station).

Among the local public transport agencies, Toronto and Brampton follow the grid network pattern advocated by Mees, while Mississauga and York region networks are primarily designed around key destination hubs. Arguably, Brampton Transit's grid network of bus and rapid bus routes carries fewer passengers (70,000 weekday boardings) than the similar route structure in place with TTC (1.4 million weekday bus and 2.8 million weekday system boardings) due to differences in urban form, population and density, which drive different LoS.

Both Mississauga (119,000 weekday boardings) and York Region Transit systems provide a high level of transfer connectivity to the Toronto network at key interchange points near their respective jurisdictional boundaries. Other regional operators are smaller in scale and operate varying LoS and route structures; only four local providers adjacent to the City of Toronto provide a direct interface with the TTC network, but those interfaces feed significant volumes of passengers into the TTC network.

The TTC system provides route interfaces between four other local bus networks and the regional GO Transit system, but there is no fare integration (trips between TTC and other systems require payment of a second fare). For TTC trips within the City of Toronto, a single flat fare structure applies for all trips irrespective of the number of transfers or distance required to make the trip. Given the intense land use focus in the CBD, however, the TTC operates a multi-modal network consisting of frequent local buses and a small number of CBD-oriented express routes from outlying areas of the city, coupled with an extensive streetcar (tram) network serving higher capacity routes in the urban core. The subway (metro) system is the spine of the public transport network; its four rail lines serve well over a million passenger boardings on an average weekday, two of which provide the high capacity required to serve passenger trips into the city centre (two other rail lines are effectively feeder routes onto the two primary lines). The subway system, and particularly the high degree of transfer integration between bus and streetcar routes, plays a central role in the success of the overall public transport network in serving equally well both the CBD-destined trips and trips with non-CBD origins and destinations.

Contrary to Mees' assertion that the operating context is solely responsible for Toronto's success, the dense urban form across the city of Toronto, coupled with its large CBD core, provides the framework for high levels of ridership for both TTC and GO Transit networks, while the flat-fare system promotes a highly effective use of fleet and operating resources along TTC's grid network for both the dominant CBD-orientation of trips. In spite of the lack of fare system connectivity, GO Transit feeds riders into the TTC subway system at Union Station; Mississauga's transit system has a dedicated hub at TTC's Islington subway station, and York Region Transit's local and bus rapid public transport services connect at Finch, Downsview Finch, and Don Mills subway stations.

Unlike other system structures focused on serving the CBD trip, TTC's grid network serves trips with non-CBD origins and destinations equally well. TTC offers high-frequency service in outlying areas but provides that service with lower capacity bus routes reflecting the lower demand associated with lower levels of urban and suburban density. In short, Toronto's urban form has allowed the TTC to 'right size' modal capacity in bus, streetcar and subway corridors through a grid network that serves a 'many-to-many' trip origin–destination pattern.

Centrality and connectivity in public transport networks and their significance for transport sustainability in cities (Scheurer and Porta 2006)

Study type: Qualitative: Best practice publications for practitioners (with elements of quantitative research approaches)

This paper assesses the applicability of centrality and connectivity indexes used for the analysis of urban street systems to assess connectivity in public transport networks. This paper focuses primarily on the urban context in which transfers between public transport services can be made rather than on the operating characteristics of the public transport system that may or may not be conducive to transfers.

TCRP-111 Elements needed to create high ridership transit systems (Transit Cooperative Research Program et al 2007)

Study type: Qualitative: Best practice publications for practitioners

This guide for practitioners identifies feeder services, among many other measures, only at a high level when citing public transport agency system performance improvements. It provides insufficient data to separate productivity gains from various methods identified to improve ridership.

Urban bus transit route design using genetic slgorithm (Pattnaik et al 1998)

Study type: Quantitative research

This study evaluates the 'optimisation problem of minimising the overall cost (both the user's and the operator's) incurred' in network design. Urban bus network design is undertaken through a variety of approaches, one of which is a system analysis approach using a transport assignment model to derive optimum parameters for headways, route spacing and travel time (including wait time). Various methods have incorporated heuristic route design or fuzzy logic and linear programming used in airline route planning and scheduling. This study focuses on genetic algorithm as a high-level simulation of an adaptive system in urban bus network design. In bus route network design, the primary aim is to determine a route configuration consisting of a set of public transport bus routes and associated schedules that achieves the maximum or minimum value of the desired objective within a set of constraints. Minimising operator and user cost (including travel time) are among those objectives. Key limitations of this model are the high degree of complexity, limited accessibility for use by planners, and significant computational requirements.

A new computational model for the design of an urban inter-modal public transit network (Peng and Fan 2007)

Study type: Quantitative research

A software tool based on this model was developed to provide useful reference for transport planners in carrying out service planning, routing and scheduling for an inter-modal transit network. This research focused on an integrated service approach using bus feeders into a rail system, identifying irregularity in service area and uncertainty in demand as key challenges. The author notes that few studies in the literature deal with the design of an integrated transit network (typically a set of rail lines fed by bus services). The study used a simple network of a single rail line and a number of straight feeder bus routes in a rectangular service region. The model optimised the rail and feeder bus routes to minimise total cost. The author concludes that a major constraint in the applicability of these studies to the design of an intermodal public transit network is the irregular service regions and network structures, which were assumed to keep the problem geometrically simple enough to be analytically solvable at the expense of losing practical applicability. The theoretical example designed to test the algorithm involved a simplistic service area of 10 analysis zones.

Transit route network design problem: Review (Kepaptsoglou and Karlaftis 2009)

Study type: Quantitative research – literature review

Planning and designing a cost and service efficient public transport network is necessary for improving its competitiveness and market share. This study describes the TRNDP and its focus on the optimisation of a number of objectives representing the efficiency of public transport networks under operational and resource constraints, such as the number and length of public transport routes, allowable service frequencies and number of available buses.

Network design elements are part of the overall operational planning process for public transport networks. For example, passenger flows between a CBD and suburbs dictate the design of radial routes while demand for trips between different neighbourhoods may lead to the selection of a circular route connecting them. Anticipated service coverage, transfers, desirable route shapes and available resources usually determine the structure of the route network. Route shapes are usually constrained by their length and directness with the goal of keeping route shapes as straight as possible between connected points, the usage of given roads and the overlap with other transit routes. The desirable outcome is a set of routes connecting locations within a service area, conforming to given design criteria.

TRNDP models can be grouped into six categories:

- analytical models for relating parameters of the public transport system
- models determining the links to be used for public transport route construction
- models determining routes only
- models assigning frequencies to a set of routes
- two-stage models for constructing routes and then assigning frequencies
- models for simultaneously determining routes and frequencies.

Most studies seek to optimise benefits to the users and to the system. User benefits may include travel, access and waiting cost minimisation, minimisation of transfers and maximisation of service coverage, while benefits for the system are maximum utilisation and quality of service, minimisation of operating costs, maximisation of revenues and minimisation of the fleet size used. These are typically represented as the minimisation of user and system costs.

Some studies address specific objectives from the user, the operator, or the environmental perspective. Passenger convenience, the number of transfers, revenue and capacity maximisation, travel time minimisation and fuel consumption minimisation are typical study perspectives. These studies either attempt to simplify the complex objective functions needed to setup the TRNDP or investigate specific aspects of the problem, such as objectives and the solution methodology. This paper identified over 60 studies published in the last four decades that have addressed the TRNDP, each of them adopting different approaches and assumptions.

Evaluating the urban public transit network based on the attribute recognition model (Qi-Zhou Hu et al 2010)

Study type: Quantitative research

This study evaluated three methods used to evaluate urban public transit networks: a fuzzy comprehensive evaluation method used, a data envelopment analysis and a grey relational evaluation method.

Intelligent agent optimisation of urban bus transit system design (Blum and Mathew 2011)

Study type: Quantitative research

The TRNDP seeks a set of bus routes and schedules that is optimal in the sense that it maximises the utility of an urban bus system for passengers while minimising operator cost. Because of the computational difficulty of the problem, finding an optimal solution for most systems is not possible. Instead, a wide variety of heuristic and meta-heuristic approaches have been applied to the problem to attempt to find near-optimal solutions. The routes and frequencies should optimise passenger costs in terms of the public transport demand satisfied, the total travel time and number of transfers. At the same time, the problem solution should minimise the operator costs, which are a function of variables including distance travelled by buses and the number of buses.

Designing robust rapid transit networks with alternative routes required (Laporte et al 2011)

Study type: Quantitative research

This model for the rapid transit network design problem assumes the mobility patterns in a metropolitan area are known. This implies the number of potential passengers from each origin to each destination is given. This study also assumes the locations of the potential stations are given. The goal of the model is to design a network by determining which nodes serve as stations and how to link them by railway lines, serving as many trips as possible within a construction cost budget constraint.

On designing connected rapid transit networks reducing the number of transfers (Escudero and Muñoz 2011)

Study type: Quantitative research

This research focused on optimising a network to reduce transfers, when given a set of potential station locations and a set of potential links between them. The TRNDP basically consists of selecting which stations and links to construct without exceeding a given budget, and determining an upper limit on the number of noncircular lines from them in order to maximise the total expected number of trips.

Applications of graph theory and network science to transit network design (Derrible and Kennedy 2011)

Study type: Quantitative research – literature review

This network nature of public transport systems has been widely studied in the past, in particular with respect to passenger flow and vehicle operations. In contrast, the literature on the geometric (or topological) nature of public transport networks seems to be relatively limited. As the study of networks is gaining momentum in the literature, and as new tools such as GIS are becoming more readily available to study urban systems, the authors of this paper feel that much effort may be concentrated on this topic in the coming years.

Although graph theory and network science have evolved from the same origins, their paths have diverged. In transportation, graph theory was first used as a means to gauge economic development, and in a few cases for network design purposes (in particular for public transport). On the other hand, network science was mainly developed to purely study the structure of networks, to identify network properties, and sometimes to assess the effects of these properties on such characteristics as robustness. As a result, these two worlds do not seem to overlap, and their usefulness for public transport planning at the moment may be limited.

Consequently, although there seems to be much potential in using a network perspective to study public transport, several hurdles will have to be passed. This is all the more relevant considering public transport systems are likely to grow substantially in the coming decades, and their designs can be determining for the future of our cities.

Research on public transit network hierarchy based on residential transit trip distance (Jian et al 2012)

Study type: Quantitative research

The notion of multilevel public transport network planning has been widely acknowledged and adopted. Some studies have considered route hierarchies, while others focus on specific linkages, such as feeder routes for a rail network. This research focused specifically on the residential trip origin to a given rail station using a feeder, attempting to assess impacts of route hierarchy and route length. Specifically, the research focused on assigning route types, such as local routes versus mass routes, to connect to railway stations.

Their model assumes that the layout of the system is rational and a typical square grid with proportional spacing. A model for optimal trip distance of each hierarchy type of routes is proposed based on features of passengers in the public transit system. The research seeks to contribute to the theory of hierarchy configuration of public transit networks and provide a feasible approach to network planning.

Robust optimisation model of bus transit network design with stochastic travel time (Yan et al 2013)

Study type: Quantitative research

Most existing methods for bus network design assume the constant in-vehicle travel time. The assumption in this research is that bus travel time is variable because buses usually operate on roads with different traffic conditions and weather circumstances. Thus, in-vehicle travel times of buses should be taken as a random variable, considering its daily variations. This solves the TRNDP by better predicting variability in bus travel time in the scheduling process.

Optimal design of the feeder bus network based on the transfer system (Deng et al 2013)

Study type: Quantitative research

As the two main transport modes in an urban public transport system, the rail line usually plays the role of the transport trunk, while the feeder bus network services act as a branch of and a supplement to the rail line.

The authors suggest the integration and coordination of urban rail service and the bus network can effectively promote the service efficiency and simultaneously improve the financial status of the system. Coordinated schedule optimisation of the two modes could lead to operating cost savings. Some cities, such as Atlanta, Miami and Washington DC, gave top priority to the bus/rail coordination during the development process of the transportation systems.

Each bus line in the feeder-bus system usually connects to a special railway station and serves a sequence of bus stops with a certain frequency. Thus, the FBNDP can be described as follows: for a given urban rail line, the stop locations and the passenger travel demand between bus stops and railway stations, the optimal feeder bus routes, and their frequencies are determined so as to minimise the passenger travel cost and the bus operation cost.

The existing research on the FBNDP mainly follows two approaches, that is, the analytic approach and network programming (also known as mathematical programming).

Most early research used analytic approaches to deduce the optimal route spacing, operating headway and stop spacing based on assumptions regarding the shape of the street geometry and the spatial distribution of the passenger demand. According to the assumption of the early research, the demand is distributed in a rectangular region in which an existing rail line is serviced (accessed) by some parallel bus routes perpendicular to the rail line.

In recent decades, the network programming approach has been introduced to deal with the FBNDP. In this approach, the urban transport network is usually represented by a graphic framework, in which nodes denote bus stops or railway stations and links denote route segments between the two successive nodes. For simplicity, it takes bus stops as the origin and the rail station as the destination of the travel demand.

This model assumes that a feeder bus network mainly transports transfer passengers between the bus and the railway system and operates under a strict set of rule-based constraints. In this model, a railway station in the network is also the destination. Consequently, as with most models, the input constraints and assumptions limit the simulation of real-world scenarios where passengers could be travelling between several feeder modes, or where destinations may also be located off the railway route and accessed only by another feeder. Although most studies focusing on feeder systems include a railway mode, a suitable methodology could also be applied to bus-only trunk and feeder network, provided a model could more realistically predict the movements in more complex networks.

Summary

A review of the relevant research publications and journal articles saw the following patterns emerge:

- There are numerous references to public transport network planning in qualitative research, but relatively few qualitative studies focus on the network benefits of public transport systems. Among the qualitative studies reviewed:

- Australia and Norway studies are cited as works that are informative from a 'personal perspective' or 'opinion' point of view. They may provide a useful overview to those interested in public transport, but they provide little practical guidance for implementation.
- Several Transportation Cooperative Research Board (TCRB) reports provide guidance and cite, in general terms, suggesting performance improvements have been made in cities evaluated relating to feeder bus networks. TCRB reports typically utilise national data reporting or agency surveys as their basis, but they provide an insufficient data analysis framework for any conclusions to be drawn with respect to specific influences of feeder routes on networks.
- Both types of qualitative studies provide case studies that could potentially inform this review, but case study examples do not provide methodologies replicable in other contexts.

• In contrast to qualitative studies, there have been numerous quantitative studies related to transport network planning over the last half century. Virtually all quantitative studies are designed to test one of several commonly recognised analytical or mathematical approaches in order to solve the TRNDP under a very specific set of contextual circumstances.

  - Many authors test a theoretical algorithm under a highly specific set of circumstances and validate results with a single case study, while many academic articles test results against a simplistic hypothetical case study.
  - Some authors explicitly recognise their approach involves a high degree of complexity, significant requirements for reliable and consistent data, notable computational requirements (often exceeding the capabilities of modern personal computers), and limited accessibility of the proposed model to public transport planners.
  - Most quantitative studies focus on the role of feeder bus routes in making the connection to a single railway station, with differences among studies being context and application of specific analytical approaches or mathematical models. Few models test the 'many to many' origin–destination problems associated with the TRNDP, but the few studies attempting to do so are limited to small corridors due to the extensive data requirements and computational challenges associated with such evaluations at the network level. Moreover, these studies typically prescribe strict rules for the passenger assignment process, rules that aid in simplifying the analysis but contribute to less realistic simulation scenarios.
  - No study effectively assessed the role of a broader feeder bus network in serving regional mobility functions in a mixed bus and rail network; one recent study that attempted a broader multimodal evaluation proved effective but limited by computational capacity to a simplistic hypothetical situation due to limitations with data input and computational capacity. The scenario tested was as bimodal bus-rail system with a simple hierarchy of local, feeder and express bus routes, coupled with a rigid set of transfer rules within an analysis system of 10 transportation analysis zones and a limited number of bus stops within each zone.
  - Few studies contemplate the hierarchy of feeder services within bus-only or bus dominant networks where transfer points are less likely to be concentrated at clearly defined station nodes.
  - At least one study has attempted to assess the effectiveness of bus-to-bus, bus-to-tram and bus-to-train transfers in a variety of urban development contexts. This study recognised a high degree of variability in the extent to which urban development and design parameters supported the inter-modal/inter-route transfer function), but the study attempts to solve challenges with the urban context of transfers, not operational or ridership issues related to the public transport service itself.

There appears to be a modest body of qualitative research on public transport network planning at the broad system level, represented by case studies, and a substantial body of analytical and mathematical research on public transport network connectivity issues in highly specific contexts, represented by limited application in proofs. From the scientific (quantitative or evidence-based) perspective, the body of knowledge around public transport network-level movements is still in its infancy, and current mathematical models and computational capacity may still be inadequate to answer effectively the research question at hand:

'What is the economic value of public transport services as a network, including feeder services, and what short and long-term value do additions contribute to the network as a whole?'

Appendix B: Calculating change in accessibility using Google Maps

The following steps outline the process for establishing both the walk catchment, and the portion of this area that would experience reduced access to public transport as a result of a spatial change in service coverage. Consideration is given to the walk access to the current network services, and how this will alter as a result of any service change proposed. While GIS technology provides the most precise tool for undertaking these calculations, Google Maps offers a good alternative for transport planners to easily establish a good understanding of the route catchment areas. This then enables the number of households affected to be calculated and an assessment of their demographic profile made.

1 Establish a 10-minute walk (800m) catchment around the area under review as shown in figure B.1.

Figure B.1 Walk catchment for last four stops of route

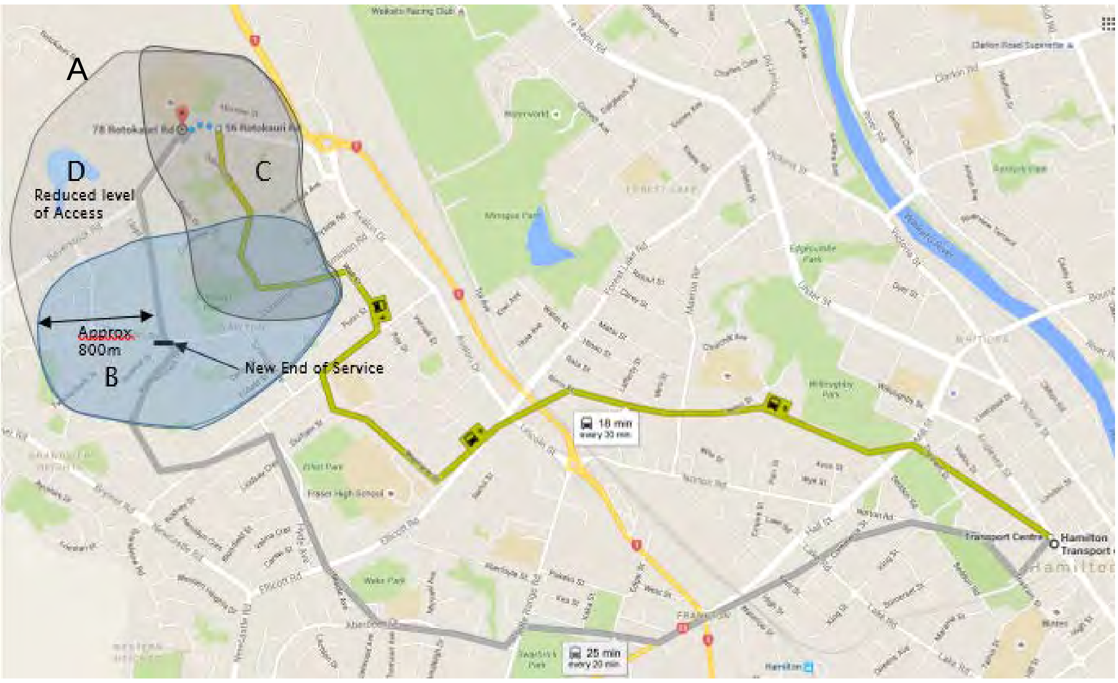
2 Determine the portion of catchment within 800m of the new end of service, shown as area B in figure B.2.

3 Of the area outside the 800m catchment of the end of the new service, determine the area within 800m of adjacent frequent services. This is shown as area C in figure B.2.

a The remaining area marked as area D in figure B.2 illustrates the area that will be impacted by a reduced level of public transport access as a result of removing the last four stops of route 8.

b The number of households in area D and their demographic makeup can then be determined and assessed.

Figure B.2 Overview of accessibility impact of service review



Appendix C: Case study 1: Trip lengths from HOP card data

This section provides a graphical presentation of the trip distance travelled (by fare type) on the Auckland network by unique HOP card IDs originating in the Mission Heights study area (spatial example), and evening users of the route 500 (temporal example).

Figure C.1 Distance travelled on the Auckland network by adults

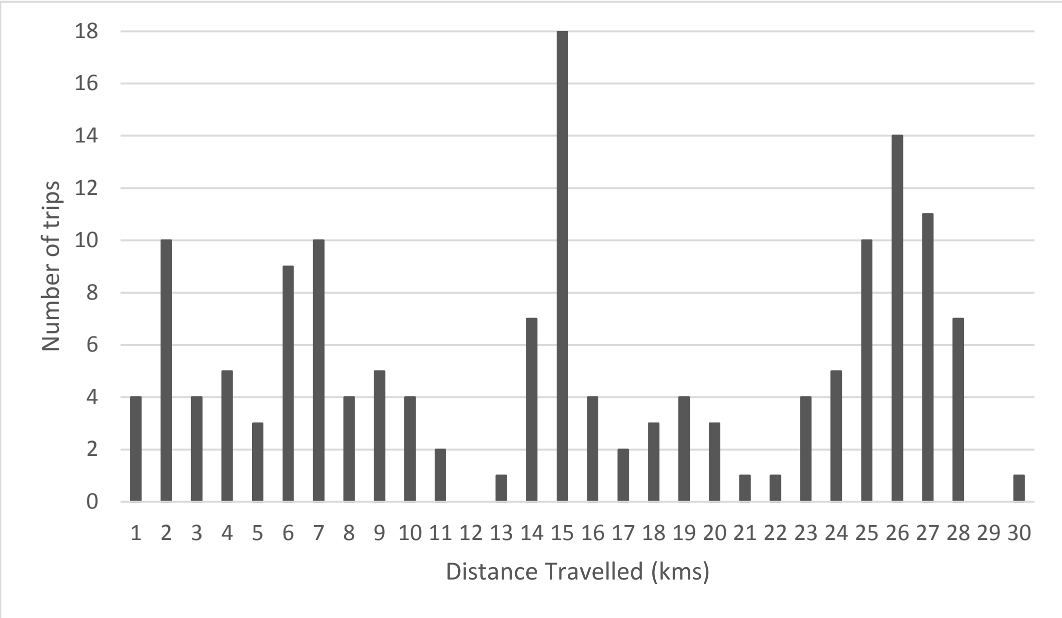


Figure C.2 Distance travelled on the Auckland network by children

Figure C.3 Distance travelled on the Auckland network by secondary students

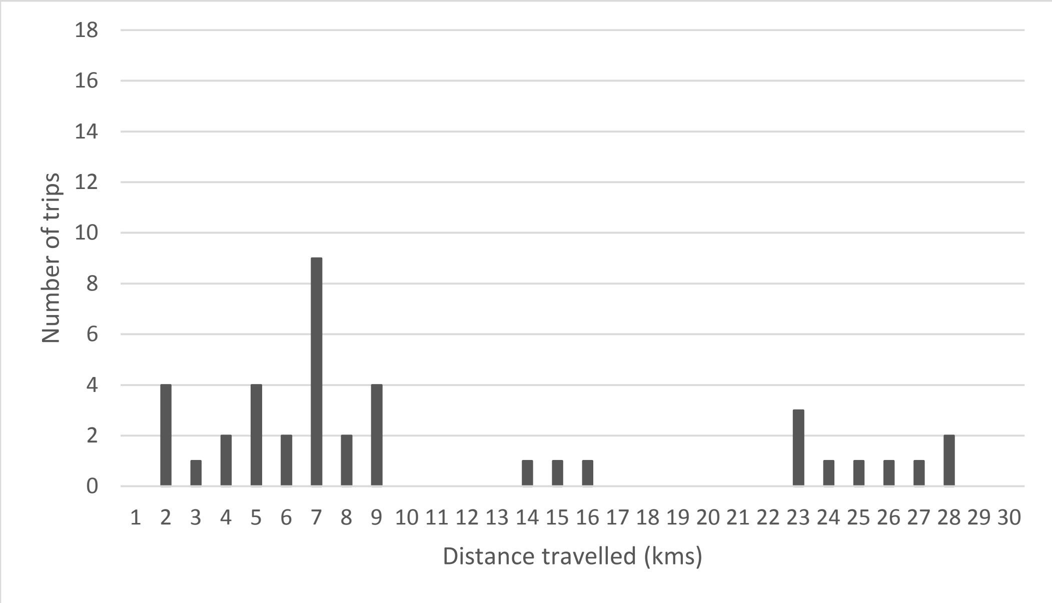


Figure C.4 Distance travelled on the Auckland network by tertiary students

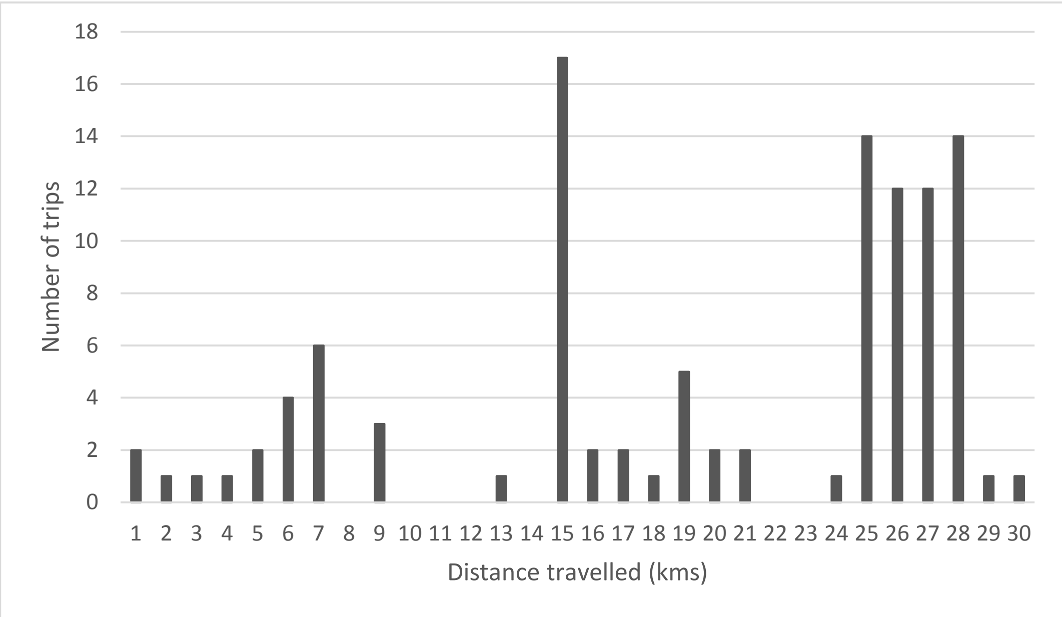


Figure C.5 Distance travelled on the Auckland network by SuperGold card holders

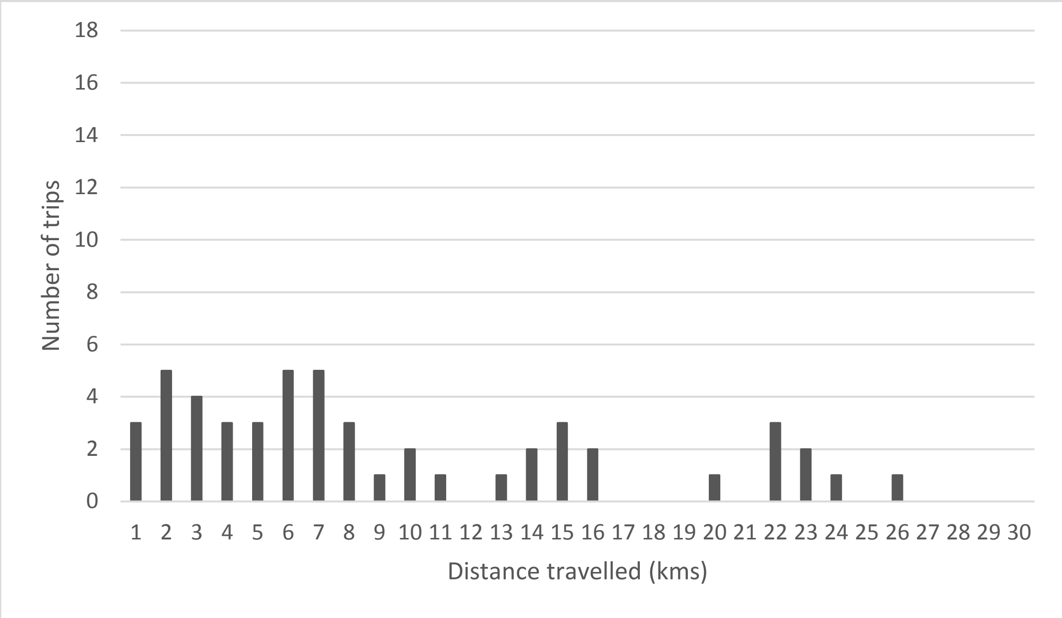


Figure C.6 Distanced travelled by on route 500 after 7pm by adults

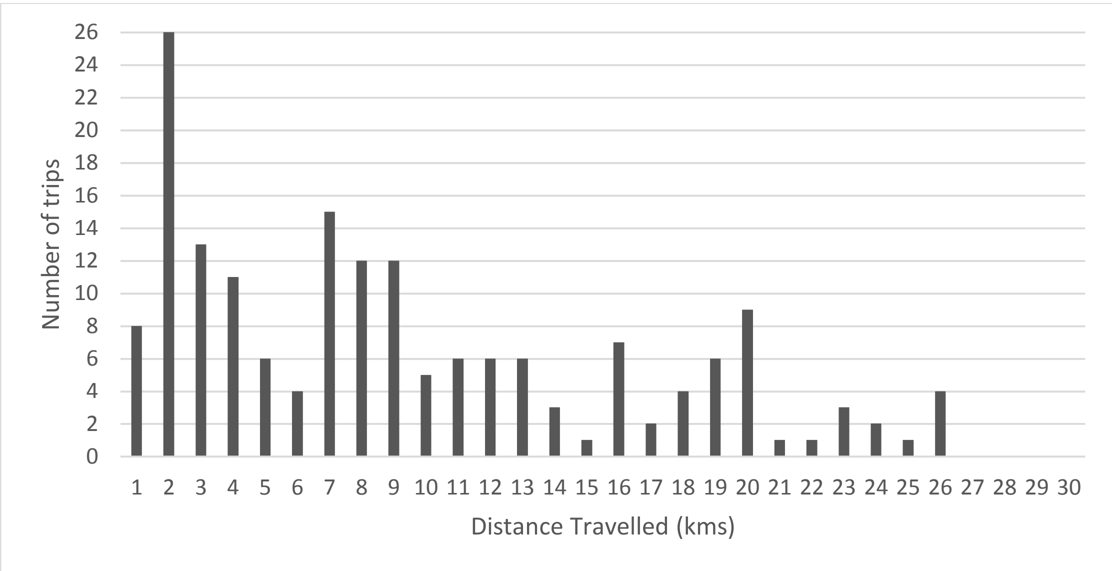


Figure C.7 Distance travelled on route 500 after 7pm by children

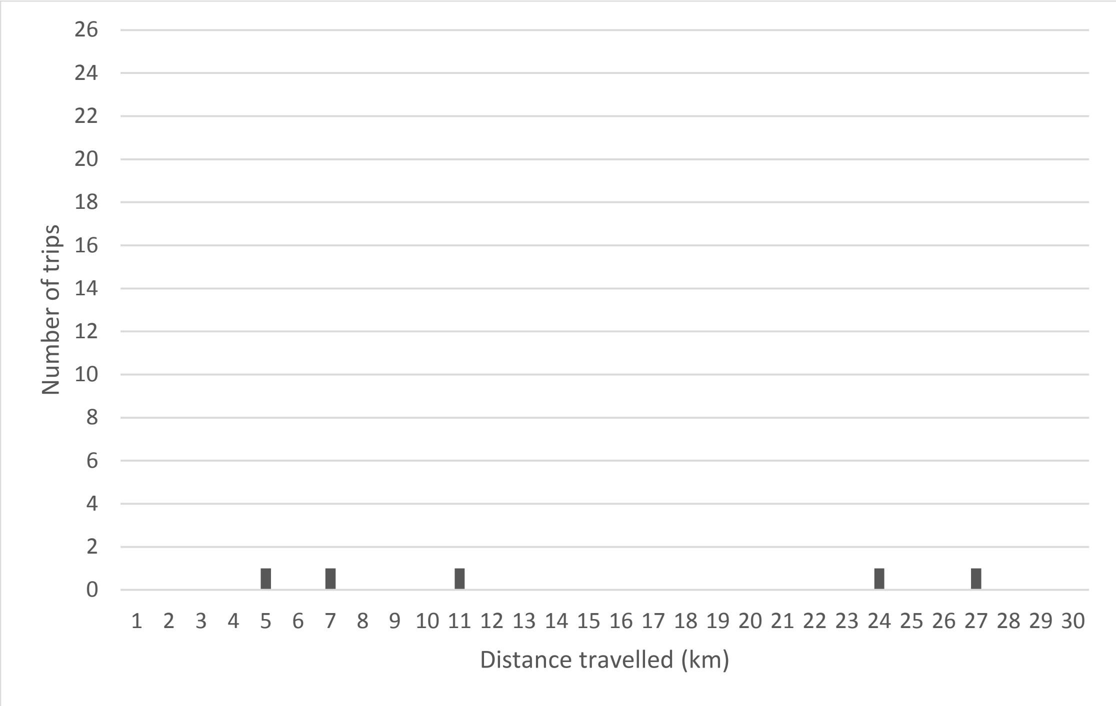


Figure C.8 Distance travelled on route 500 after 7pm by secondary school students

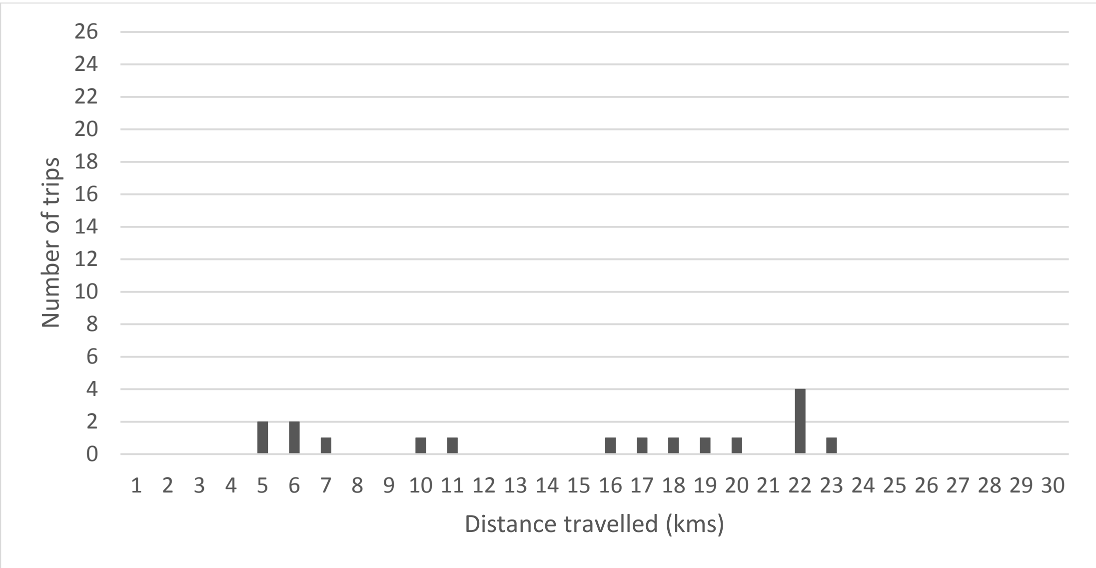


Figure C.9 Distance travelled on route 500 after 7pm by tertiary students

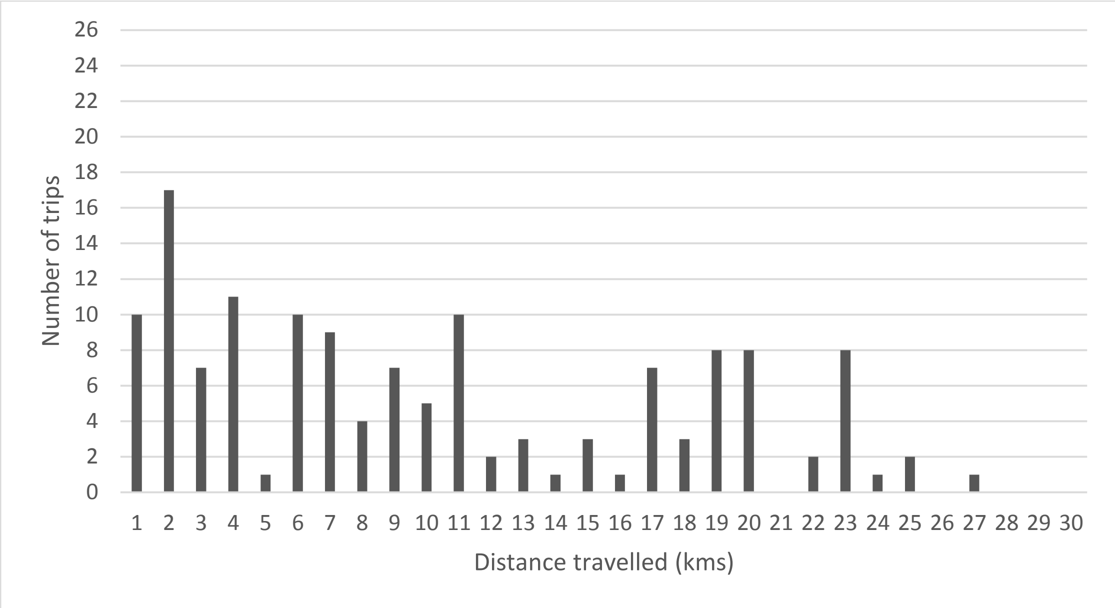


Figure C.10 Distance travelled on route 500 after 7pm by SuperGold card users

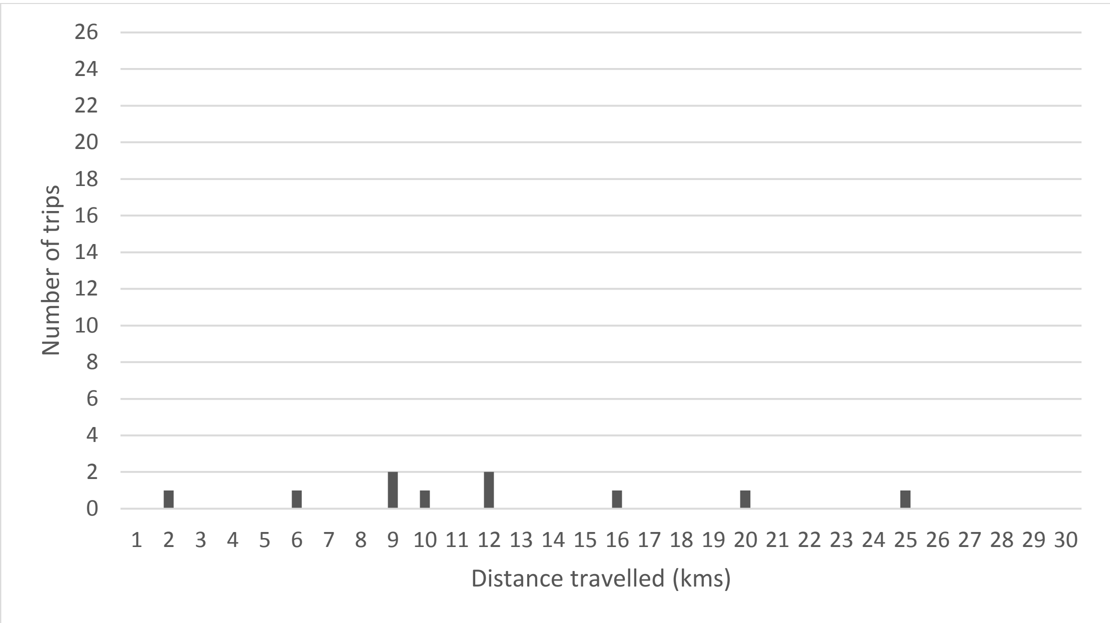


Figure C.11 Distance travelled on route 500 after 7pm by wheelchair users

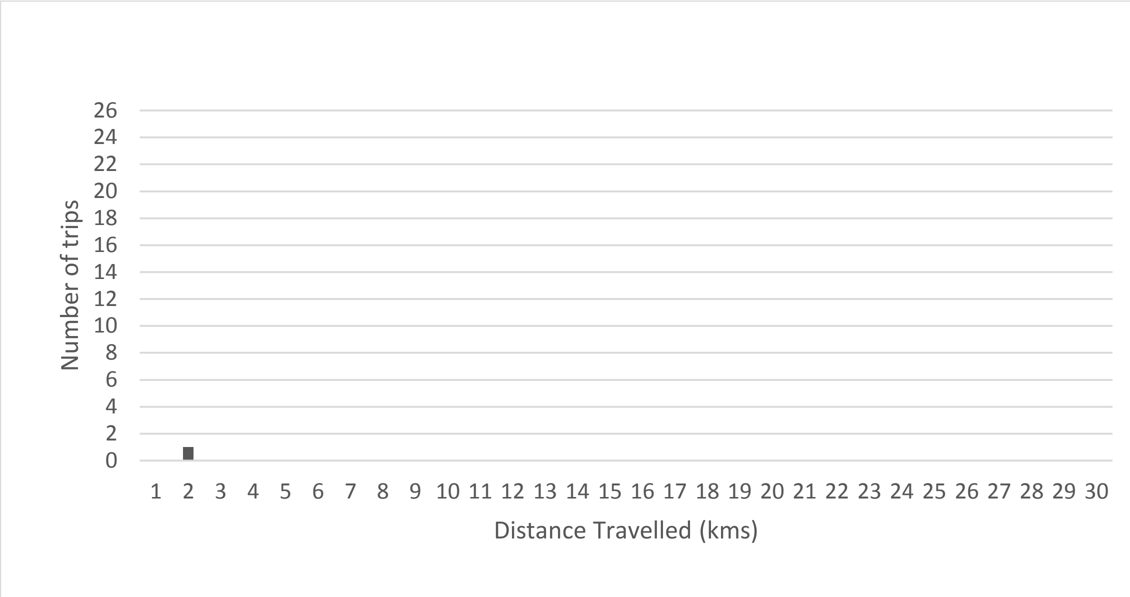


Figure C.12 Distance travelled on additional services on the Auckland network by adult evening users of route 500

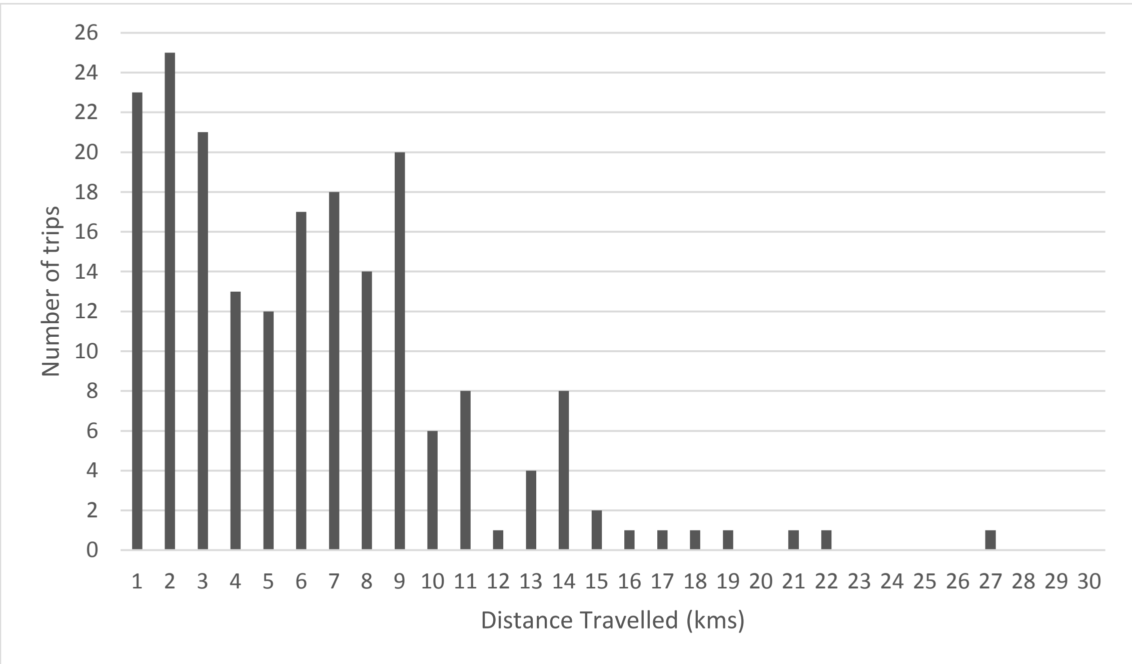


Figure C.13 Distance travelled on additional services on the Auckland network by children evening users on route 500.

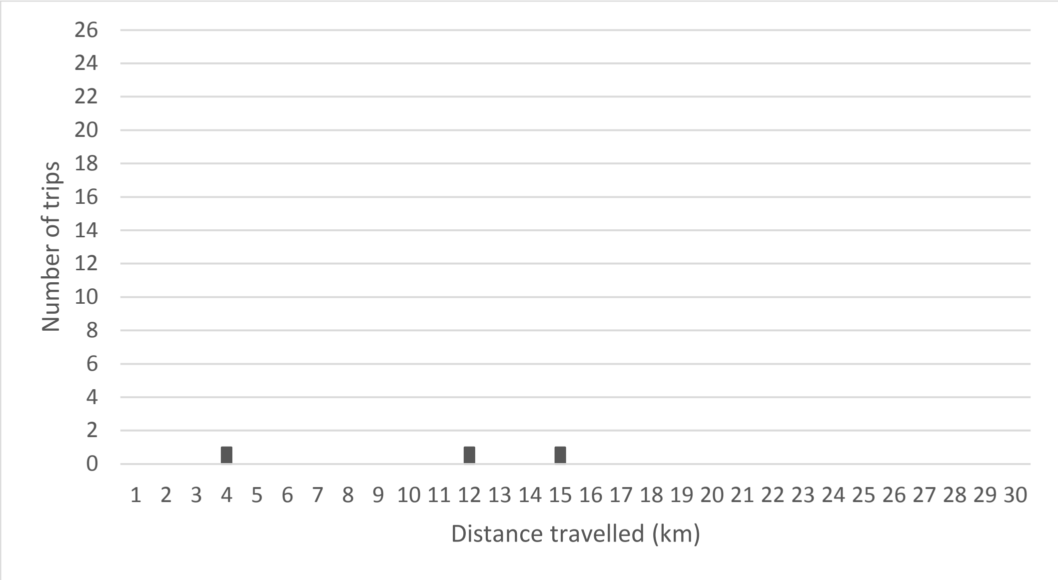


Figure C.14 Distance travelled on additional services on the Auckland network by secondary student evening users of route 500

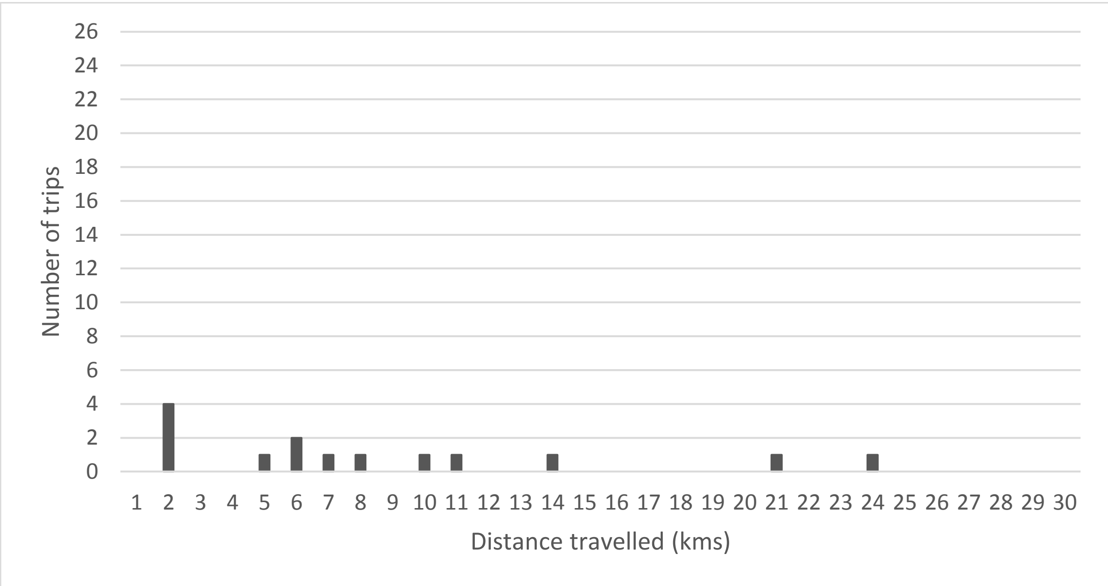


Figure C.15 Distance travelled on additional services on the Auckland network by tertiary student evening users of route 500

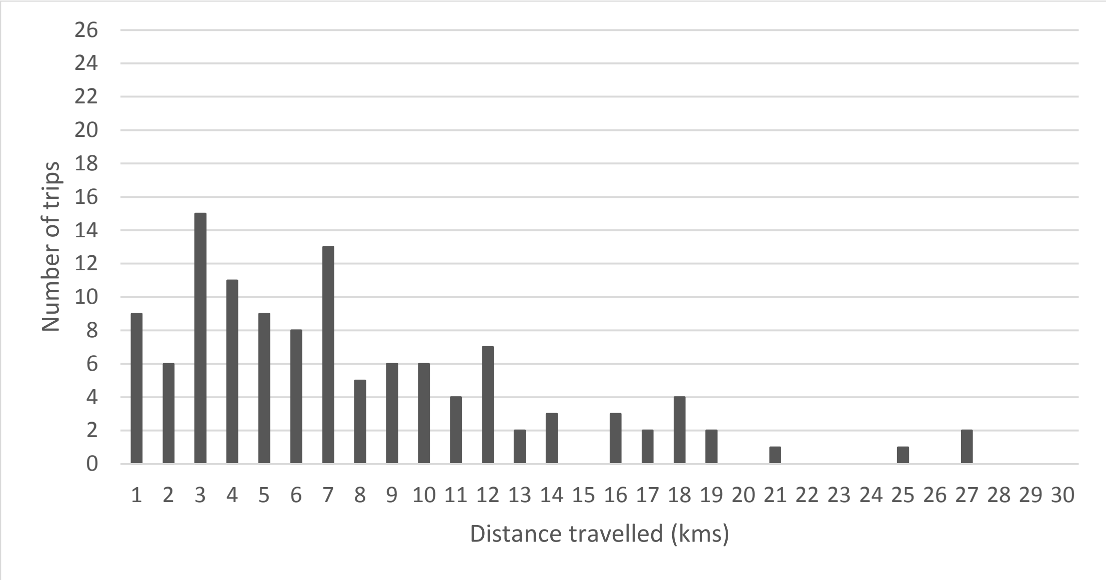


Figure C.16 Distance travelled on additional services on the Auckland network by SuperGold card evening users

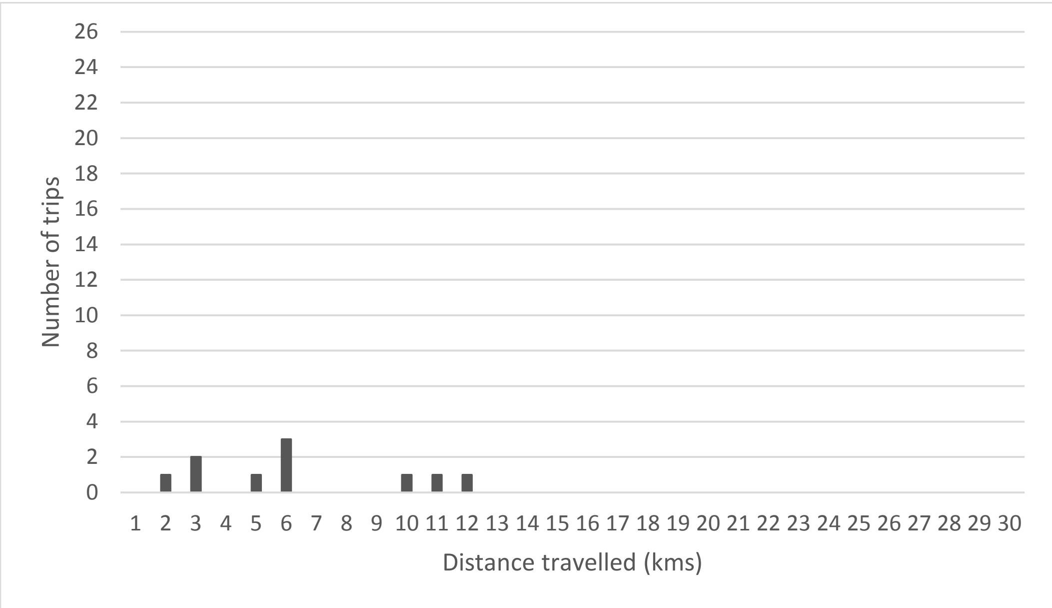
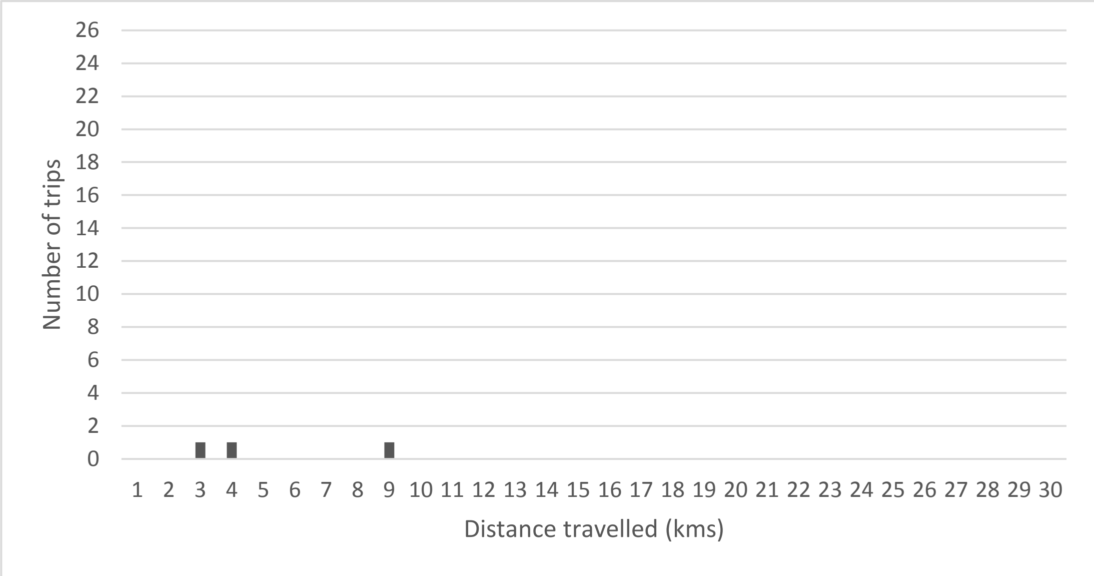


Figure C.17 Distance travelled on additional services on the Auckland network by wheelchair evening users of route 500



Appendix D: Glossary

ATAM	Auckland Transport Accessibility Model
BCR	benefit cost ratio
CBD	central business district
CSR	community street review
ECAN	Environment Canterbury
EEM	*Economic evaluation manual* (NZ Transport Agency 2016)
FBNDP	feeder bus network design problem
GIS	global information system(s)
GPS	Government Policy Statement
GTFS	general transit feed specification
GTHA	Greater Toronto Hamilton Area
HOP	branded Auckland integrated fares system
IAF	Investment Assessment Framework
LTA	Land Transport Act
MAE	multiple accounts evaluation
MOT	Ministry of Transport
NLTF	National Land Transport Fund
NLTP	National Land Transport Programme
NRC	Northland Regional Council
NZTA	New Zealand Transport Agency
PPDG	*Pedestrian planning and design guide* (NZ Transport Agency 2009)
PTOM	public transport operating model
RLTP	regional land transport plan
RPTP	regional public transport plan
SEQ	Southeast Queensland
SP	simplified procedures
TCRB	Transit Cooperative Research Board
TRND	transit route network design
TRNDP	transit route network design problem
TTC	Toronto Transit Commission

Appendix E: Case studies – economic and demographic evaluation

This is an Excel file located at www.nzta.govt.nz/resources/research/reports/616.