

# Assessing the value of public transport as a network

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## 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 including community and political sensitivities.

## 1. Introduction

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 generally only meets Government targets 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 they 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 acknowledge the social impacts of a public transport service.

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 by valuing the contributions of individual services 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 fully inform public transport network reviews.

## **2. Literature review**

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. The literature focused 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.

### **2.1 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 seamlessly 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).

#### **2.1.1 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.

The network effect centres on the 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).

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.

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.

### **2.1.2 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). 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 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.

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).

### **2.1.3 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 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). 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).

### **2.1.4 The 'last-mile' and 'first-mile' effect**

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 al (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. Bike racks on buses and the provision of services such as Park and Ride, Uber, and bike share programmes can help ease the last mile effect for some people in some conditions. Improving access by active transport modes has been cited as an effective solution to combat the first and last-mile problem. 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).

## **2.2 Public transport value elements**

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 (Forckenbrock 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).

### **2.2.1 Economic impacts**

The NZ Transport Agency Economic Evaluation Manual (EEM) (NZ Transport Agency 2016) sets out the economic evaluation procedures to be used for calculating benefits and costs of land transport activities, and is the principal transport infrastructure funding document in New Zealand.

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 effects 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).

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).

### **2.2.2 Direct user, social and health impacts**

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). Public transport can also 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).

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 (Goavorthy 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. 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.

The broad purpose of the stakeholder consultation was to:

- understand how stakeholders value public transport
- understand the components and considerations that are critical to decision making
- understand the data sets that 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.

#### **3.1 Consultation outcomes**

Funding was 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, but at the same time 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.

Stakeholders unanimously agreed that a standard methodology for valuing public transport networks that was useful and useable would be helpful to inform evaluation and decision making.

The stakeholder interviews provided valuable insight into current mechanisms and thoughts together with available resources that contributed to the manner in which network value and change propositions were managed. Some of the overarching themes that emerged and were expressed (explicitly or implicitly) by stakeholders were:

- Network planning decisions are largely cost, capacity and funding driven
- The value of low volume services is not well understood
- Valuing social elements is critical; including the importance of option value
- Public transport networks are generally mature and not agile or reflective of current and future transport needs
- There is a political influence element to decision making
- Public transport investment is often at conflict with other transport modes
- Accessibility, coverage and connectivity measures are all important components

#### **4. Network value assessment approach**

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 as a whole that would be directly transferrable to this research.

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 studies (Auckland and Waikato) were developed to demonstrate the practical application of this four-stage assessment approach.

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The case studies illustrate how an assessment of the value of a service can be developed to inform decision makers about the full implications of the removal or reduction of service provision. Examples include the removal of spatial coverage such as feeder services, and the reduction of temporal coverage such as evening services.

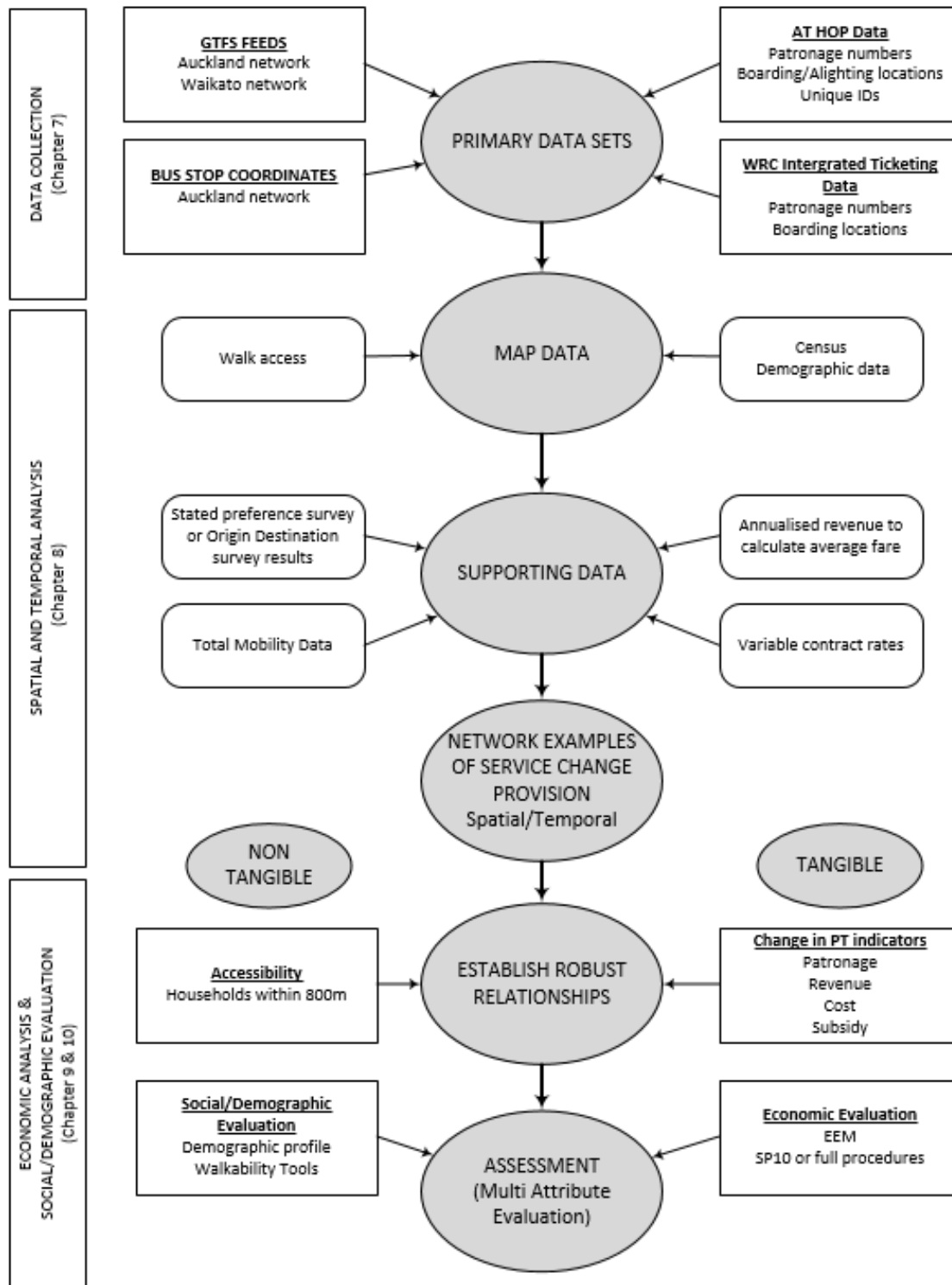
A variety of data sources can be used to assess public transport at a specific area or route level. Many aspects contribute to determining the value of public transport coverage across the network. Having the ability to isolate trips, trip distances, and user behaviour and make up, allows for a more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

The Auckland and Waikato case studies were developed to practically demonstrate how these data sets can be integrated to learn more about the impacts of a change in service provision. This includes an assessment of:

- 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.

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 1

Figure1: Data collection, analysis and assessment framework



## 4.1 Methodology

While some benefits are tangible and able to be enumerated, others 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 NZ Transport Agency EEM (NZ Transport Agency 2016) framework provides the foundation for completing an economic assessment of a component of a public transport network. The research team identified the framework would require modifications to consider enabled trips (network effect), trip length and mode shift.

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 EEM Simplified Procedure 10 were suggested to value these additional trips and to adjust the 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 were incorporated into the evaluation using available census data, and a Level-of-Service approach was applied to 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 employment which in turn can improve people's economic opportunities. These benefits were found to be challenging to enumerate.

For more specific details as the assessment framework methodology, interested readers are directed to the full research report for further details (Hyde and Smith 2017).

## 5. Research outcomes

The outcome of the research is the presentation of a framework (with Auckland and Waikato case studies) 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.

Only the Waikato case study is presented in this paper and interested readers are directed to the full research report (Hyde and Smith 2017) for more details.

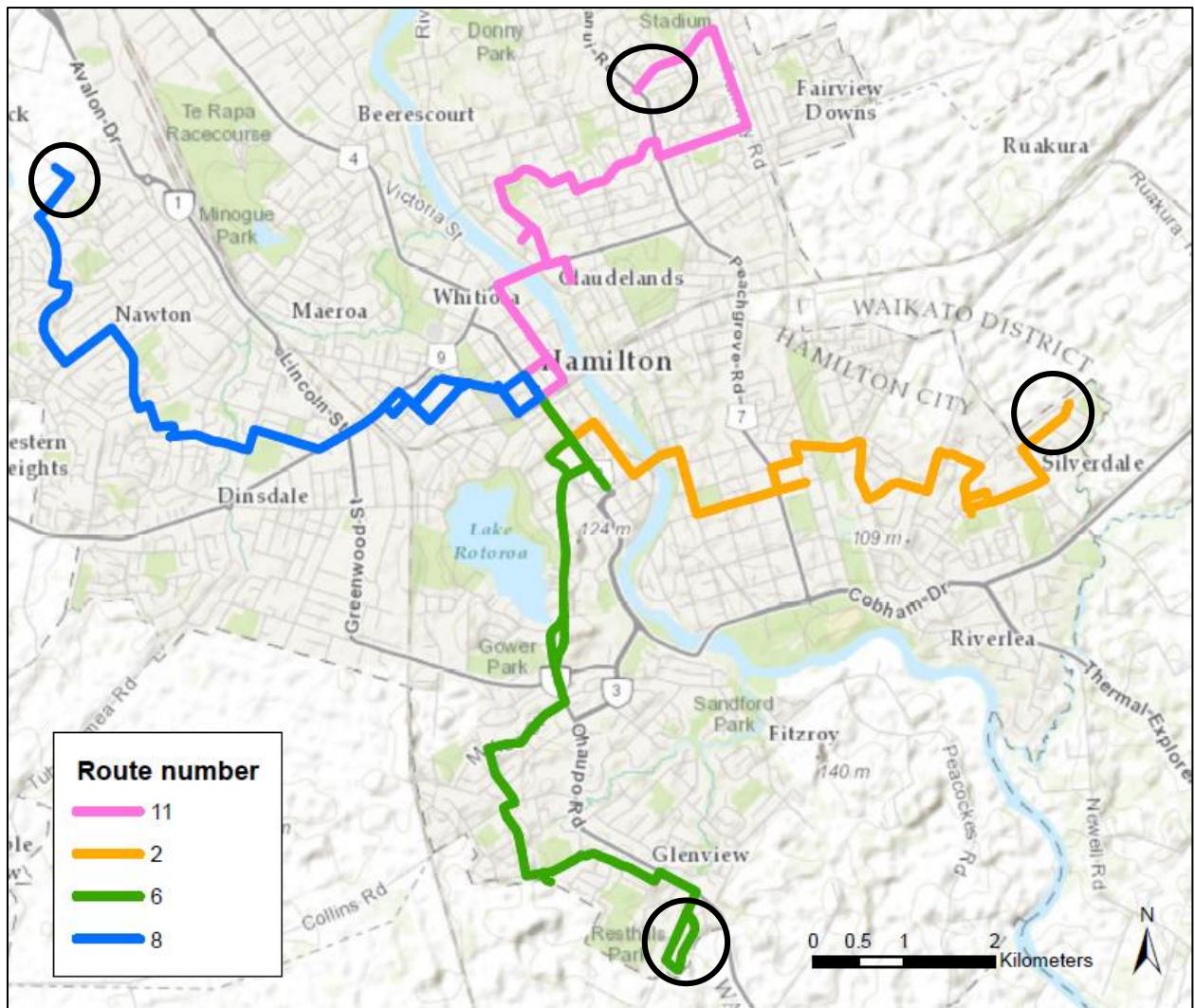
## **5.1 Case study Waikato**

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 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.

The social and accessibility evaluation for each of the four different areas has been developed and shown in Figure 3 which demonstrates 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.

This evaluates each route using the EEM economic assessment which is a modified version of the EEM Simplified Procedure 10 which also captures all enabled trips, adjusts the assessment for actual trip lengths and provides a good overview of the different levels of impact public transport service coverage has on the community it services based on demographic data from Statistics New Zealand.

Figure 2: Waikato case study routes



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 Benefit Cost Ratio (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 of the areas that routes 6 and 11 service, 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.

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Figure 3: Social and demographic evaluation for Waikato routes assessed

Options		Waikato				BCR		
		Including enabled trips - Off peak only				Low	Medium	High
Economic Assessment		Route 2	Route 6	Route 8	Route 11	<2	2-4	>4
	BCR	2.6	1	1.7	0.5			
	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			
Social/Demographic Evaluation						Level of Impact		
	# Households in 10 min walk catchment	1181	1715	2442	2640	Low	Medium	High
	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% +
Accessibility Evaluation						Level of Impact		
	# of households > 800m from similar PT service	13	1	13	0	Low	Medium	High
	Gradient	<7%	<7%	7-8%	<7%	<7%	7-8%	>8%
	Pedestrian Environment	Average	Average	Average	Average	Above average	Average	Below average

<sup>1</sup> 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.

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 further detail pertaining to the two case studies the reader is directed to an Excel spreadsheet which is available with the full research report and is available to be downloaded from [www.nzta.govt.nz/resources/research/reports/616](http://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 is available for the industry to aid in the assessment of public transport service reviews in the future.

## **6 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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