The North Shore Busway Evaluation

By MG Smith, BA Foy and Z Andjic

Abstract

A busway has been proposed on the North Shore of Auckland of a number of years. It runs from Albany in the north to the Auckland Harbour Bridge, along a new two lane carriageway adjacent to the motorway.

The carriageway is intended to carry buses, and High occupancy vehicles, and this dual function led to a number of issues as to who would fund the facility, and to what extent. That in turn led to issues as to how the busway should be evaluated, as the requirements of the two key funding agents (namely Transfund New Zealand and Infrastructure Auckland) were different.

This paper describes the busway concept and its various components, and summarises the requirements of the key stakeholders. It then details the analytical process, data availability and confidentiality issues, and the modelling tools used in the evaluation. In particular, it looks at the options that were available at the outset, and the way these had to be adapted as the project progressed.

Of necessity, the paper stops short of including the results of the evaluation, as these have not yet been considered by the funding agencies. Nevertheless, it does highlight the issues that the profession will need to consider in future when analysing proposals that have a significant public transport component.

Background

The North Shore Busway, or BRT as it is now known, is essentially the addition of two new lanes to the east of the Northern Motorway in Auckland from Albany to the Auckland Harbour Bridge. It is designed to enable a limited number of high occupancy vehicles to use it during the morning peak, whilst providing a high quality service for buses.

In addition to the roadway, there will be five ‘stations’ where passengers can access the busway, either by means of ‘Park n Ride’ facilities, or by transfer from other services. The service structure has been designed to follow this concept.

The Busway is recognised as the preferred rapid transit mode for the Northern Auckland corridor. Public transport use tends to be the most cost effective in dense urban corridors, due to high load factors and relatively low cost per passenger kilometre. On major urban routes fares often cover all operating costs and in some cases the capital costs as well. These are also conditions where congestion, parking, crash risk and pollution costs tend to be greatest, due to traffic density and high land values. In such conditions, a public transport system that substitutes for automobile travel can provide particularly large benefits. To be able to achieve high patronage levels the public transport needs to include:

- Additional routes, expanded coverage, increased service frequency and hours of operation.
- Reduced and more convenient fares (such as discount for frequent users)
- Bus or HOV lanes (bus priority traffic signals and other measures that reduce delay to PT vehicles)
- Comfort improvements
- Improved passenger information and marketing programs
- Park and Ride facilities.

At present, public transport in Auckland urban area is still experiencing low patronage levels and high congestion on roads due to automobile traffic in peak periods with the tendency for off peak travel also becoming congested.

Transport model development and history

The model was originally built in 1987/1988 and than updated in 1999 using 1991 census data to provide the land use data. The original model was build as a tool to assist with a transportation study. In order to be used in the busway project, the model needed to be extended into and past the Auckland CBD (Figure 1). The model comprised only a morning peak (7am-9am).

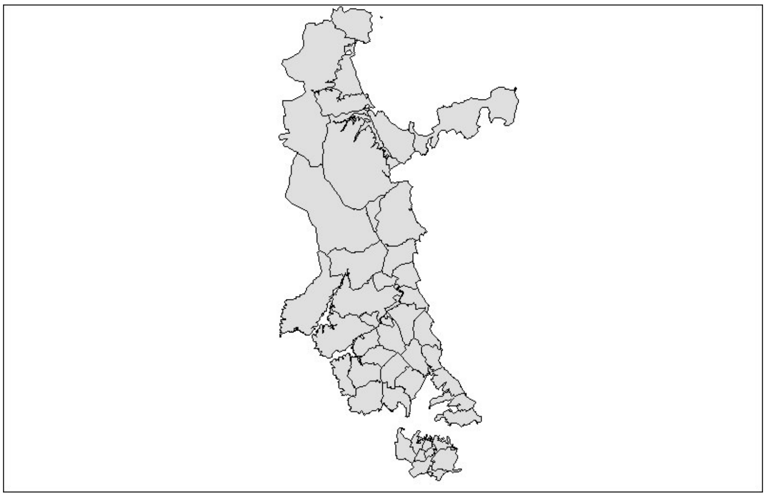

Figure 1 Extent of study area

Prior to the modal split distribution the model was altered to accommodate a multiclass (car drivers and HOV drivers) and public assignment by coding certain links to be used only by HOV or public passenger user classes. The purpose of such a model was to provide the necessary information for the evaluation of the busway stations for applications to Infrastructure Auckland, the assessment of required passenger transport services and to provide the necessary information for evaluation under ATR procedures for specific services if necessary.

Although the original model was built as a four step the modal split phase changed to use a ‘pivot point’ model that reallocated trips between the modes on the basis of the relative change in accessibility of each of the modes, where accessibility is measured through cost of travel. For each trip Tij and for mode k.

$$\rho'_k = \frac{\rho_k \exp(-\lambda \Delta C_k)}{\sum_k \rho_k \exp(-\lambda \Delta C_k)}$$

Where: $\Delta C_k = C'_k - C_k$

And:

- ρ'_k is the forecast proportion of (person) trips made with mode k
- ρ_k is the base (pivot) proportion of (person) trips made with mode k
- ΔC_k is the change in cost of travel on mode k
- C'_k is the 'new' generalised cost for mode k
- C_k is the base generalised cost for mode k
- λ is the logit scale factor

Generalised costs are derived from public and vehicle multiclass assignment outputs. Public transport assignment outputs are explained in more details below.

As part of the calibration and validation of the model it was necessary to ensure that the model provided adequate sensitivity for changes in cost. The factors reviewed and the calibration of the model is discussed below.

Model Concept

The model has the following form. Derivation of the total person trips derived by summation of the individual 'observed' mode components and forecast into the future using growth factor techniques. This is followed by application of a pivot point model to obtain mode split and to adjust for changes in generalised costs in the future year, both for base and option cases.

The basic steps are:

- Run the (signed off) 3 step model at 2000 and compare car driver trips against 2000 (present day) traffic counts, once the distribution assignment loop has converged.
- Prepare a car passenger matrix using the resulting car driver trips, and 1991 occupancies
- Prepare a PT matrix by massaging the 1997 Beca matrix
- Growth factor the individual matrices to future years and apply a pivot point mode split for the base and options to reflect the changes in generalised costs.

Derivation of Trip Matrices

Year 2000 trips

Modal split modelling comprised the distribution of the following modes:

- Car driver
- HOV driver

- HOV passenger
- Bus passenger
- Ferry passenger

Trip matrices for each of these modes were derived for 2000 in a variety of ways.

Car Driver trips were derived from the North Shore transport model which is reported in the model building and validation report prepared by Gabites Porter in May 2000 [3]**.** This model was peer reviewed for Transfund New Zealand. The validation of the model at 2000 is reported in the model building and validation report forwarded to Transfund's reviewer in October 2000.

High occupancy vehicle trips were assumed to be 16% of the car driver matrix. The 16% figure was derived from surveys of vehicles entering the motorway system in the morning peak period. The matrix estimation technique was used to match HOV counts on motorway on-ramps. The definition of an HOV is consistent with the Priority Lane evaluation and assumed a 2+ management regime.

Car passengers were assumed to be a percentage of the car driver trips based upon the same surveys used to estimate HOV's.

Bus passenger trips were derived from the intercept surveys carried out for the derivation of the APT model and used trip matrices from the observed data.

Ferry passenger trips were also derived from the APT data using the observed matrices.

These trips were assigned to the network, and the resulting flows validated by checking against counts.

Future trips

Future trips for 2005 and 2011 were initially estimated as follows.

Car driver trips were derived by using future landuse, including households, employment and car ownership as an input to the model. This process generated a new matrix of car driver trips.

Car passenger and ***HOV driver*** were estimated by using the growth in car driver trips as a proxy for the growth in car passenger and HOV driver.

Public transport and ***ferry trips*** were derived using the growth in households to provide the new PT trips generated (as the origin factor), the change in employment was used as a factor to provide the growth in trips to different destinations (the destination factor).

Prior to the modal split distribution the model was altered to accommodate a multiclass (car drivers and HOV drivers) and public assignment by coding certain links to be used only by HOV or public passenger user classes. The purpose of such a model was to provide the necessary information for the evaluation of the busway stations for applications to Infrastructure Auckland, the assessment of required passenger transport services and to provide the necessary information for evaluation under ATR procedures for specific services if necessary.

Although the original model was built as a four step the modal split phase changed to use a 'pivot point' model that reallocated trips between the modes on the basis of the relative change in accessibility of each of the modes, where accessibility is measured through cost of travel. For each trip Tij and for mode k.

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Generalised costs are derived from public and vehicle multiclass assignment outputs. Public assignment outputs are explained in more details below.

As part of the calibration and validation of the model it was necessary to ensure that the model provided adequate sensitivity for changes in cost. The factors reviewed and the calibration of the model is discussed below.

Factors affecting public transport patronage and calibration of lambda

Elasticities have been used in the development of the pivot model to ensure that the model provides adequate responses to changes in cost. Table 1 shows the elasticity of PT use with respect to various factors. For example, a 1% increase in regional employment is likely to increase public transport patronage by 0.25%, while a 1% increase in fare prices will reduce patronage by 0.32% all else being equal.

Table 1. Factors affecting public transport patronage

Factor	*Elasticity*
Regional Employment	*0.25*
Central City Population	*0.61*
Service	*0.71*
Fare Price	*-0.32*

(Kain and Liu, 1999) [2]

Improved schedule information, easy to remember departure times (e.g. 'clock face' timetabling), and more convenient transfers have been shown elsewhere to increase public transport use, particularly in areas where service is less frequent.

Lambda (also known as the logit scale factor, or λ) is used to calibrate the relative sensitivity of the model to changes in key inputs. The calibration of the pivot model has been on the basis of achieving a fare elasticity of -30%. In order to calibrate lambda the PT fares were doubled (a 100% increase in fare) and the logit scale factor λ varied from 0.0015 to 0.0035 to test sensitivity. This testing showed PT demand to be linearly dependent on λ as shown in Figure 2. A final figure for lambda was derived of .26 giving a fare elasticity of -28.29%. This figure is within an internationally acceptable range.

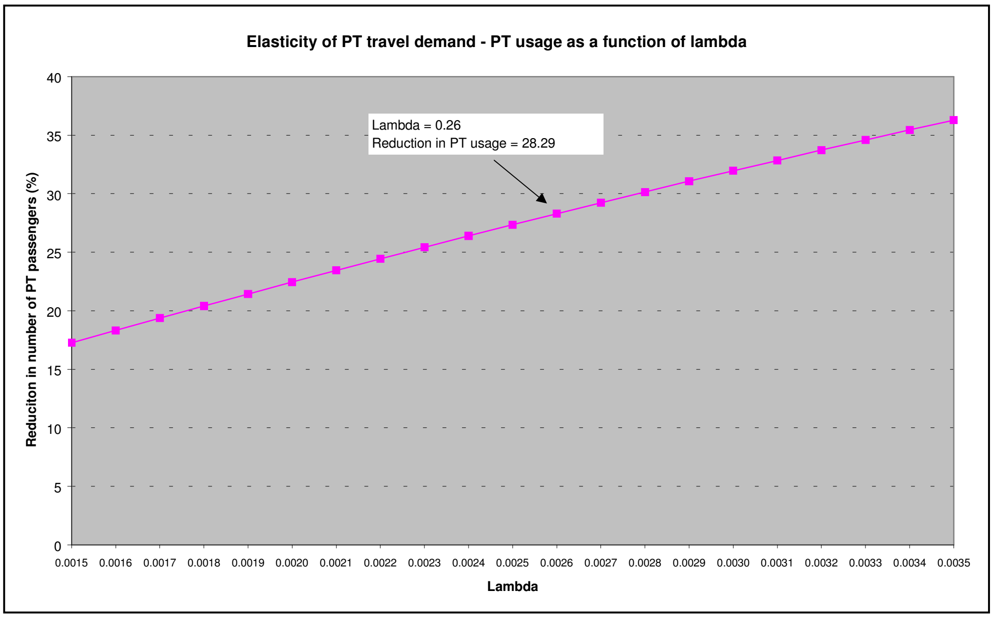

Figure 2. Lambda Calibration

Public Transport Assignment Model

The PT assignment model is analogous to the vehicle assignment and is used for assigning PT trips onto the network. Unlike conventional vehicle assignment, PT assignment assigns the bus passenger matrix onto a fixed set of routes. Similar to vehicle assignment the decision of which route is taken is based on least cost algorithm. The main difference between the vehicle and public transport assignment is in the way the matrix is loaded. The public transport assignment is modelled using a dynamic assignment model where the modelled period and the matrix are divided into slices and passengers are released in intervals starting from the beginning of the modelled period. A dynamic assignment approach is necessary because of the way that buses run following a fixed timetable, and the decision by each passenger as to which service or services will be taken is compounded by the time dimension. This level of detail was required so that the Auckland Regional Council could calculate the funding gap, that is the difference between the system operating cost and fare box revenue.

a) The single ride trip will occur if:

$$T^{1}_{A} > T^{i}_{S} + T_{F} + T_{C}$$

Where: T^1_A is the time at which the first available bus arrives at the bus stop A.
T^i_S is slice release time where the number of slices is *i*.
T_F is access time by foot.
T_C is access time by car to the park'n'ride station

The difference between the left and right hand side in the inequality above represents the waiting time T_W:

$$T_W = T^1_A - T^i_S + T_F + T_C$$

The waiting time has to be greater or equal to 0 and less or equal to maximum waiting time otherwise the trip can not occur.

$$T_{W(max)} \geq T_W \geq 0$$

b) The multi ride trip will occur if
the single ride trip condition is satisfied for the first bus service used, and

$$T^2_B \geq T^1_B + 30sec$$

Where:

T^1_B is the time at which the first bus arrives at the bus stop B.
T^2_B is the time at which the second bus departs at the bus stop B.
30sec is the minimum time allowed for the passenger transfer.

The difference between the first bus arrival and the second bus departure represents the waiting time:

$$T_W = T^2_B - T^1_B$$

Therefore T_W and has to be greater or equal to 30 seconds and less or equal to maximum waiting time $T_{W(max)}$ for the trip to occur:

$$T_{W(max)} \geq T_W \geq 30sec$$

If the maximum number of transfers is 3, then another condition has to be met for the trip to occur:

$$T^3_C > T^2_C + 30, \text{ and}$$

$$T_{W(max)} \geq T_W \geq 30sec$$

Where:
T^2_C is the time at which the second bus arrives at the bus stop C.
T^3_C is the time at which the third bus departs at the bus stop C.
T_W is $T^3_C - T^2_C$
$T_{W(max)}$ is the maximum waiting time.

Further constraints are the maximum inter-zonal cost and the maximum number of transfers. They cannot exceed values specified in the parameter file.

The inter-zonal cost for PT trips is derived as the sum of several components:

- wait time cost
- walking time cost
- park'n'ride cost (if used)
- fare cost

Fare cost component can further be broken into

- riding cost
- transfer penalty cost

Riding cost depends on the fare type and the type of switch for multi or single route selected in the parameter file.

The fare types are

- adult fare
- adult fare with concession
- child fare
- child fare with concession

All bus routes are divided into a number of fare sections and the bus fare is derived depending of which fare section crossed. Depending on the switch selected two possible scenarios for derivation of riding costs are shown in Figure 3. If a single ride option is selected the cost of transfer is added and the fare section structure is reset to zero after the transfer point. If a multi ride option is selected after adding the cost of transfer the fare section structure doesn't change provided the passenger carries on with the same operator. Therefore with the single ride option selected the fare cost is derived as follows:

$$\$2.2+\$1.08+\$2.2=\$5.48$$

and for the multi ride option:

$$\$1.08+3.8=\$4.88$$

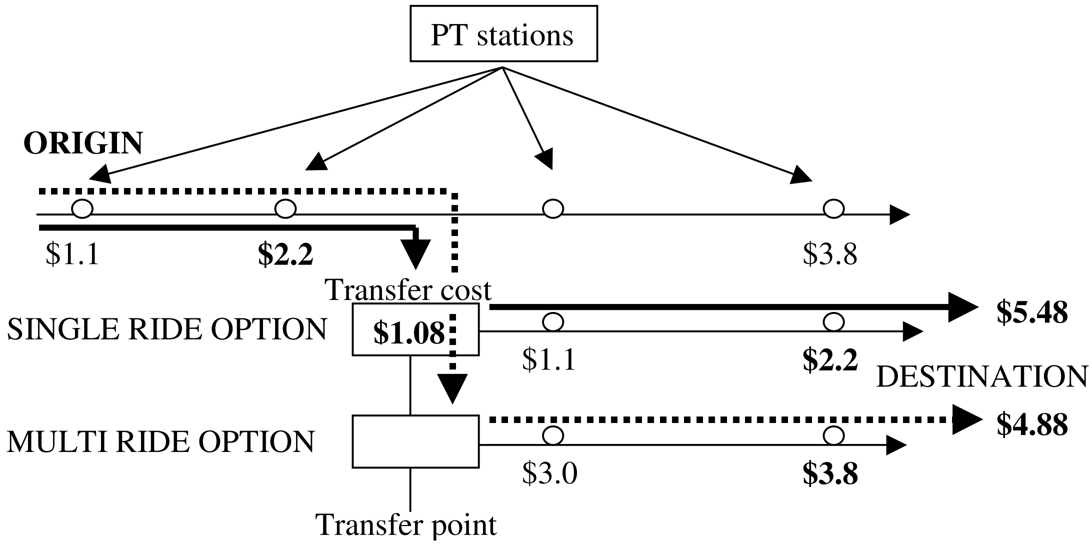

Figure 3 - Derivation of Riding Costs

Node numbers allocated for the transfer stations are also specified in the parameter file.

If a car is used as part of a PT trip (park'n'ride) than the car cost is added and it consists of:

- In vehicle time cost, and
- In vehicle distance cost
- Parking cost

Time and distance costs are derived from the loaded vehicle network. During the assignment the link time is multiplied by 1.3 [1] to allow for the time lost at bus stops where the boarding and alighting of buses occurs. The route file defines express routes where passengers can board buses only on certain stations. If the node on an express bus route has the negative sign the link time from vehicle loaded network is not multiplied by 1.3.

Public Transport Model Outputs

The public transport assignment outputs a series of matrices representing various time and cost components:

- Service time for the service numbers greater than 20.
- Service time for the service numbers less than 20.
- Average walk time
- Average wait time
- Average car cost
- Average fare cost

Other matrices output by the public transport assignment are:

- Average number of fare sections crossed
- Average number of transfers.

It is also possible to track down the interzonal paths, transfer station used and the bus services that are used by passengers to get from origins to destinations. This information is stored in the path file. This file also lists origin and destination nodes for each bus service used and the park'n'ride nodes if these facilities are used to complete the PT trip. The path file also contains information about each of the slices loaded, the release time and the cost in dollars for that trip portion. If the trip happens to be the one where passengers transferred from one bus to another, then the node at which the transfer occurs, is recorded.

Passenger patronage per service with the time component included is reported in a separate file, which lists all services and the number of passengers getting on and off the buses along the route.

Similar to vehicle assignment loaded network is produced at the end of each run, and depending on the switch used in the parameter file loaded network will contain either PT passenger numbers or the number of buses.

The model estimates two park 'n' ride matrices, one which contains park 'n' ride trips from origins to park 'n' ride stations and another containing trips that use park 'n' ride facilities from their origins to their destinations.

Select trip analysis is also provided within the public assignment by specifying bottleneck node and two catchment nodes. Output list file reports are as follows:

- Service number with its frequency
- Number of selected trips going through catchment nodes and the bottle-neck node.
- Proportion of selected trips using only one service to get to the bottleneck node.
- Total number of trips going through two catchment nodes in that direction (this number is always equal or greater than the number of selected trips).

Evaluation

It was agreed that Beca Carter Hollings and Ferner BCHF were to evaluate the HOV lane component north of, and associated works south of the Harbour Bridge and GP were to evaluate the BRT and the associated structure (such as stations). The HOV lane was evaluated as a roading project under the Project Evaluation Manual, whilst the BRT system was evaluated as an Alternative to Roading (ATR). The two evaluations took place simultaneously with a broad agreement on ensuring consistency in inputs and outputs from the processes to avoid double counting of benefits.

The splitting of the evaluation of the HOV lane from the BRT system has required the development of compartmentalised processes which ensure that the benefits of each component is separately identified. For the HOV this has been fairly simple with the do minimum and the option networks readily identifiable. For the BRT evaluation it has been necessary to identify a process that ensures that the benefits of the HOV lane are not included, and that the benefits of services and stations can be identified. This has required the development of a do minimum which includes the HOV lane against which firstly benefits of the routes and than benefits of the stations can be assessed. There are benefits to existing PT users from the development and use of the priority lane. The travel time benefits come from the travel time savings between the shoulder lane (used currently) and the priority lane.

Evaluation Components

Prior to the evaluation, components had to be defined including service types and service scenarios used in the evaluation.

Service types

Planning for the BRT services has concentrated on the week day morning peak two hour period, 7.00am – 9.00am. This is the critical period of the day and determines the bus fleet requirements to provide the services. Four main types of services are planned:

Exclusive Busway Services (Line Haul)
These are the services operating on the busway between Massey University and the Auckland Waterfront Interchange. Investigations are currently under way to determine the desirability of these services continuing through to Newmarket. Auckland City is requiring that future bus services in lower Queen Street be provided by low emission, high specification vehicles.

Express Bus Services
These are the bus services picking up patrons in the urban areas within convenient walking distance of their homes and accessing the busway at the earliest opportunity and travelling to Auckland central. The last pick up will normally be at the busway station where the bus enters the busway and it will set down passengers as required. This will reduce the need for patrons to transfer. The terminus for these services will likely be in the Civic Theatre area and access will be via Albert Street and pass close to the Waterfront Interchange. Express services will also operate throughout the day in the opposite direction.

Local & Feeder Bus Services
These are bus services usually travelling the same routes as the express services to the busway station but instead of accessing the busway they continue on another route, thus providing the "cross-town" services. In some instances, the local services do use stations of the busway providing both a local and feeder service.

Exclusive Loop Bus Service
Two "loops" are currently proposed, one around Lake Pupuke connecting Takapuna, Milford, and North Shore Hospital to the busway at Akoranga (AUT) and Westlake, and the other connecting Albany Basin to Browns Bay. It is proposed that these services will operate in both directions at 15-minute intervals throughout the day.
Service Frequencies

Service Scenarios Used in the Evaluation

This section details the service scenarios that were considered. The do minimum provides a conceptual base that includes the HOV lane (and hence HOV benefits), the options provide for bare, and full stations.

Base case

The evaluation process begins with the existing services in 2001 to ensure that any comparisons of future services with existing services are valid. The existing bus services already use the motorway shoulder and all comparisons take this into account. Frequencies for these services have been taken from timetables and coded onto the network.

First option (S1A)

The first option undertaken looked at the way in which the busway would function using it as a route into the Auckland CBD. It provides improved travel times into Auckland but the absence of stations on express routes prevents the best service structure from being established. The number of buses crossing the Harbour Bridge during the modelled period is the same as for the second option in 2005. This was particularly important in order to have the equivalent access levels to Auckland CBD for comparison purposes.

Second option (S2A and S4A)

The second option assumed that the full BRT system was in place, including a pattern of services that made best use of the stations as well as the carriageway. It involved a service pattern that essentially treated the stations as 'hubs' and a service pattern that radiated out of these. They provide good connectivity to Auckland CBD, and also to North Shore destinations. In addition it includes Park and Ride facilities. Park'n'ride facilities can increase the PT patronage and can have a major influence on the portion of commuting trips to Auckland CBD made by public transport. Although park'n'ride facilities reduce urban traffic they may increase urban fringe vehicle traffic as motorists detour to reach facilities or make additional trips. Actual impacts of park'n'ride depends on the quality PT services, service patterns and the distribution of jobs and employment. Option S2A provides for the set of services to be used in 2005, and Option S4A provides for the set of services in 2011.

BRT Stations

BRT stations serve PT passengers throughout the modelled area of North Shore. They are used as transfer points between a busway and local routes. They also serve as mode terminals where car drivers park and board buses representing park 'n' ride and kiss and ride points.. As such they improve accessibility for potential busway users and represent major busway point of entry and exit for express services.

Conclusion

The methodology developed by Gabites Porter Consultants provides a good base for the busway economic evaluation and was accepted by Transfund New Zealand. At this stage the results of the evaluation [4] cannot be revealed as Transfund New

Zealand and Infrastructure Auckland have not received the final evaluation report. However the results may be presented at the IPENZ conference in September 2001.

References

[1] Williman and Smith, (1974)

[2] John F. Kain and Zvi Liu, "Secrets of Success," Transportation Research A, Vol. 33, No. 7/8, Sept./Nov. 1999, pp. 601-624.

[3] Gabites Porter Consultants (NZ) Ltd, North Shore Road Network Study, Building the Transportation Model, Technical Background Report, May 2000.

[4] Gabites Porter Consultants (NZ) Ltd, Bus Rapid Transit - Economic Evaluation, Technical Report, July 2001.