AUCKLAND: THE NORTH SHORE BUSWAY EVALUATION

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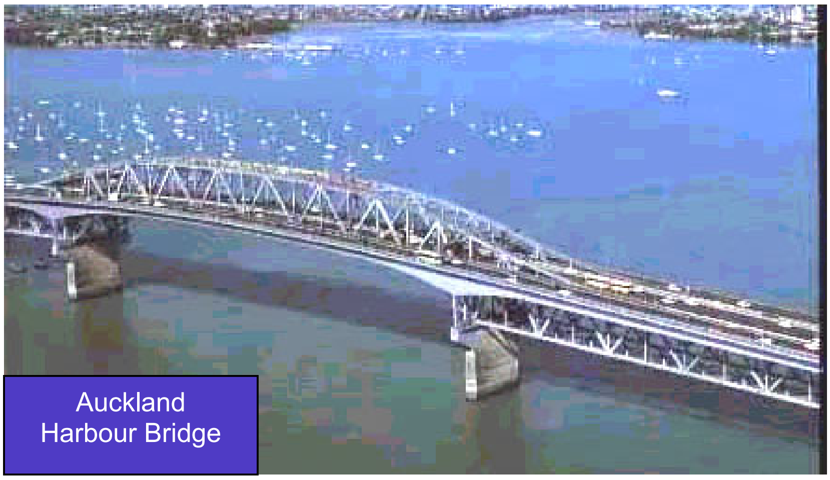
1. Background

Auckland is a sprawling city of approximately 1,2 million inhabitants covering a municipal land area of 4158 km^2.or built up area excluding islands is about 464 km^2 Auckland CBD is linked to the northern areas (North Shore City) by the Auckland Harbour Bridge, a bridge spanning about 1000m over the Pacific Ocean.



The Auckland Harbour Bridge carries around 151 000 vehicles a day (1999) and the peak am southbound direction past Esmonde interchange is 5600 vehicles per hour (1999).

There are 126 bus services operating from/to North Shore. Apart from buses another mode of transport between North Shore (Devonport) and Auckland is a Ferry service. This ferry service transports around 4400 passengers a day (both directions) or 1,6 million pa. Due to port capacity restrictions and other factors an increase is not envisaged in the short term.

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 public transport vehicles)
- Comfort improvements
- Improved passenger information and marketing programs
- Park and Ride facilities.

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

The North Shore Busway, or BRT as it is known, comprises the addition of two new dedicated lanes to the east of the Auckland Northern Motorway from Albany to the Auckland Harbour Bridge. While initially only parts of it will be 2 lane, eventually it will be a separate carriageway over its whole length. The length of this dedicated busway will be initially 8km with the future possibility of expansion taken into account. It is designed to enable a limited number of high occupancy vehicles to use it during the morning peak travelling only southwards to the CBD, whilst providing a high quality service for buses in both directions.

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.

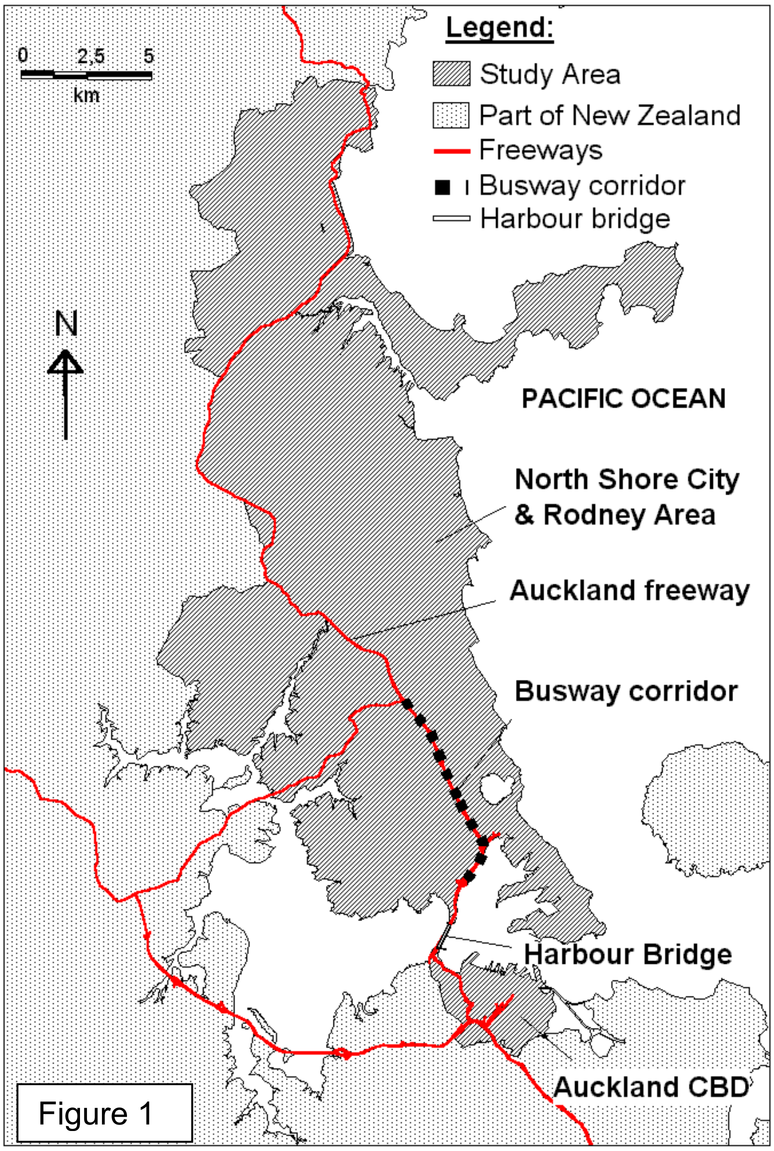

Figure 1

The brief given to the study team was to analyse the operation of the Busway and to prepare economic evaluations that would satisfy the requirements of the various stakeholders. These included Transfund New Zealand, Infrastructure Auckland, North Shore City Council, and The Auckland Regional Council. The study area for which the BRT is the focus point is depicted in Figure 1 above. The study area comprises the North Shore & Rodney areas of 272sq km and the Auckland CBD of 11 sq km totalling to 283 sq km.

The methodology chosen was based on a transport planning model which had been in operation on the North Shore for many years, although modified for this project as described later. The purpose of the model was

- to provide the necessary information for the evaluation of the Busway stations for applications to Transfund New Zealand (under the ATR procedures)
- to provide the necessary information to support an application to Infrastructure Auckland for those parts of the project that did not meet Transfund's criteria,

- to analyse the performance of required passenger transport services and to provide the necessary information for the Auckland Regional Council to calculate the 'funding gap' for on-going Public Transport subsidy, and
- to give North Shore City confidence that the Busway would not only service demand to the Auckland CBD, but would also be an integral part of the public transport system servicing the North Shore.

2. Transport model development and history

The very first model for North Shore was originally built in 1987/88 using the TRACKS modelling suite. It was a tool to assist with the Takapuna (an urbanised part of North Auckland) Transportation Study, but has been in continual use since that time. It was revalidated in 1999 using 1991 census data and the Auckland Home Interview survey data following an initial peer review by Transfund. The re-calibrated and validated model (termed the North Shore model) also developed in TRACKS was accepted by Transfund in December 1999 as a suitable base from which to develop project evaluation models. The Busway model was one of these.

In order to be used in the busway project, the Busway model needed to be extended into and past the Auckland CBD (Figure 1), and to have a mode split stage added to the 'vehicle driver' North Shore model. Also, while the North Shore model included all time periods, the decision was taken to limit the Busway model to only a morning peak (7am-9am), on the basis that most of the benefits were believed to be gained in that period.

A further change in the Busway model was the introduction of a multi-class vehicle assignment (car drivers and HOV drivers) and a public transport assignment. These TRACKS subprograms have been altered so that certain links in the network were able to be used only by HOV or public passenger user classes as appropriate.

Initially the model was built as a conventional four step model using person trip generation and distribution, a logit model for mode split and a conventional public transport and vehicle assignment. However, following a series of discussions among the key stakeholders, the mode split phase changed to use a 'pivot point' model. This model form takes base matrices by mode, usually from surveys, and then reallocates 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 (where cost of travel is a function of time and distance components). It is based on the following formula:

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

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

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

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

The inputs to the pivot model are

- the base proportions of (person) trips made with each mode.
- the base generalised cost for each mode.
- the change in generalised cost of travel for each mode.
- the logit scale factor, λ (lambda)

The output from a pivot model is the forecast proportion of (person) trips made for each mode. The modes used were:

- Car driver
- Bus passenger
- HOV driver
- Ferry passenger
- HOV passenger

The key components are the 'base' trip matrices by mode, and the generalised costs by mode.

3. The Modeling Process

The process adopted in running the model was as follows:

At 2000
Prepare trip matrices and generalised costs at 2000.
Calibrate lambda by checking elasticity response to a change in fare
Check that the assigned vehicle & passenger volumes matched counts.
At 2005
Growth 2000 matrices projected to 2005
Assign these and prepare generalised costs
Apply the Pivot model using 2005 trips with 2000 and 2005 base costs
Assign new trips and iterate to convergence
Assign to a Busway option and prepare new costs
Apply the Pivot model using 2005 trips and base and scheme costs
Iterate to convergence.
A similar process was followed for each of the Busway options.

4. Factors affecting public transport patronage - 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 public transport 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 other things 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 bus 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 bus demand to be linearly dependent on λ. A final figure for lambda was derived of 0,26 giving a fare elasticity of –28,29%. This figure is within an internationally acceptable range.

5. The public transport assignment model

The public transport assignment model is analogous to the vehicle assignment and is used for assigning public transport trips onto the network. Unlike conventional vehicle assignment, public transport assignment loads the bus passenger matrix onto a fixed set of services (or lines) but these travel on the loaded network output from the vehicle assignment so that buses experience the same travel times and delays as cars. Similar to vehicle assignment the decision of which route is taken is based on a 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 influenced by the departure time of the bus. This level of detail was required so that the Auckland Regional Council could calculate the funding gap (subsidy level), that is the difference between the system operating cost and fare box revenue.

Bus passenger trips are not currently constrained by bus capacities and this needs to be incorporated into the future versions of the public assignment software. Once this has been added different bus services could be analysed based on various measures of effectiveness including passenger congestion. The model will be able to more reliably give the required number of buses for certain routes.

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

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

Travel times including intersection delays 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. Express routes where passengers can board buses only at certain points are able to be defined, and time taken for boarding is not applied to express routes.

6. Public transport model outputs

The public transport assignment outputs a series of matrices representing various time and cost components for each O/D pair:

- Service time for the service numbers.
- 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.

7. Evaluation

7.1 Development of analytical bases

It was agreed by the stakeholders that a separate study was to evaluate the HOV lane component north of, and associated works south of the Harbour Bridge while this study was to evaluate the BRT and the associated structure (such as stations). Figure 2 shows the project as well as the proposed bus stations. The HOV lane was evaluated as a roading project under the Project Evaluation Manual[5], whilst the BRT system was evaluated as an Alternative to Roading (ATR)[6]. 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 separation 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. In the case of the HOV this has been fairly simple with the do minimum and the option networks readily identifiable.

In the case of 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 the benefits of the routes and then the benefits of the stations can be individually assessed. There are benefits to existing bus 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.

Figure 2

7.2 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)
- Express Bus Services
- 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

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 does not double count HOV benefits), the options provide for bare, and for full stations.

- Base case
  The evaluation process began with the existing services in 2001 to ensure that any comparisons of future services with existing services was valid. The existing bus services already use the motorway shoulder and all comparisons took this into account, although there is an argument that buses should not be using the shoulders at all. Frequencies for these services were 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 included Park and Ride facilities. Park'n'ride facilities can increase the bus 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 of bus 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 bus 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.

8. Results of Modelling

8.1 Population and Employment forecasts

Population and employment forecasts (see Table 2) are key factors influencing the public transport patronage. To estimate future year base matrices the public transport model growth factors the observed public transport trip productions and attractions using zonal population and employment as the main forecasting variables

Based on these growth assumptions the PT model estimates an increase of 19,8% in PT trips by 2005 and 36,5% by 2011. These estimates take into account the shifts of passengers from other modes to PT as a result of increased congestion.

Table 2: Summary of Landuse Forecasts

		North Shore City and Rodney District			Auckland City		
	Year	Forecast	Growth	%Growth	Forecast	Growth	%Growth
Household	2001	82106			9025		
	2005	88179	6072	7%	10998	1973	22%
	2011	96618	8439	10%	12935	1937	18%
Population	2001	230627			23526		
	2005	242400	11773	5%	28751	5224	22%
	2011	262282	19882	8%	33951	5201	18%
Total Employment	2001	90539			105092		
	2005	96059	5520	6%	113162	8070	8%
	2011	102883	6824	7%	121198	8036	7%

8.2 Patronage forecasts

Table 3 below shows the total patronage forecasts for the entire study area and also the bus operating characteristics which provide information on bus operating costs. As can be seen from the table bus patronage has increased in the do minimum scenario by approximately 4% per annum up till 2005 and then by 3% till 2011. With the introduction of the BRT at 2005 patronage rises from 7623 to 9104 (20%) with the bare stations option, and to 9642 with the introduction of the full BRT. Similarly in 2011 with introduction of the BRT patronage rises from 8687 to 10419 (20%) with the bare stations options and to 12,465 for the full BRT option (a) services.

Table 3: Passenger transport model results					
Year	Description	Total patronage	Total in service minutes	Total in service kms	Min/km
2000	Existing services	6 363	12 494	5 214	2,40
2005	Do minimum	7 623	11 070	5 206	2,12
2005	Option (S1A)	9 104	28 679	16 062	1,79
2005	Full BRT (S2A)	9 642	19 996	10 932	1,83
2011	Do minimum	8 687	11 768	5 207	2,26
2011	Option (S1A)	10 419	32 840	16 062	2,04
2011(a)	Full BRT (S4A)	12 465	34 079	17 082	2,00
2011(b)	Full BRT (S4A)	12 322	30 966	15 582	1,99
2011(c)	Full BRT (S4A)	12 795	28 949	14 572	1,99

8.3 Economic Evaluation Results

This involved comparing costs and benefits. The **Costs** of the options arise from three sources:

- Capital costs.
- Maintenance Costs.
- Funding Gap. The funding gap is defined in the ATR as:

> *The deficit between the…total revenue…and the service provider costs is the amount that needs to be funded by local and central government if the project is to proceed. The amount that requires funding…is the 'Funding Gap'*

The funding gap figures have been supplied by the ARC for all periods and options.

Benefits of the options when compared against the bus system operating without the busway arise from four sources of user. These are the differences between the options, and the do minimum.

- Benefits to people
- Vehicle operating costs
- Accident Savings
- Carbon Dioxide Savings

An example of the capital costs for "bare station costs" is shown below. Bare station costs include those parts of the station and access roads that are required in order to allow the stations to operate to the standard identified in Section 2.1 (Option 1 (S1A)). The bare station costs have been estimated as a percentage of the full station cost and have been pro-rated over time to give a time stream of cost. Table 4 below displays the cost of providing the full stations, access for buses to the HOV lane, and Park 'n Ride facilities

Table 4: Full Station Costs							
	Expenditure per Year ($000)						
STATION	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Total**
Akoranga	-	-	$ 656	$ 6 585	$ 2 643	-	**$ 9 884**
Westlake	-	$4 249	$ 945	$ 5 161	$ 576	-	**$ 10 931**
Sunnynook	-	-	-	$47	$576	$2 787	**$ 3 410**
Constelation	$ 3 514	$ 7 393	$680	-	$ 36	$ 697	**$ 12 320**
Albany	$ 110	$ 2 812	$ 922	$ 5 688	$ 1 277	-	**$ 10 809**
Prof. Fees	$ 1 290	$ 793	$ 598	$ 402	$ 324	$ 169	**$ 3 577**
Total	**$ 4 915**	**$ 15 249**	**$ 3 800**	**$ 17 883**	**$5 432**	**$3 653**	**$ 50 931**

Testing the different options

A series of costing calculations then follows, which are then discounted over 25 years to produce net present values (NPV) for the economic evaluation. The discounting process reduced the capital cost of $50,931m Table 4 to $41,331m. The funding gap difference arose because of the higher number of passengers using the system, and the subsidy required to meet the operating costs.

Two options were tested against the do minimum option and calculations and tables were produced for capital & operating costs, user costs and user benefits. The capital and operating cost tables are shown below:

Capital and Operating Costs (NPV) **- Option One – *Busway with bare stations***

	Do Minimum	***Option One***	***Option One net costs***
Capital Costs	0	$5,265m	**$5,265 m**
Maintenance	0	$0.136m	**$0,136m**
Funding gap	$36,072m	$70.961m	**$34,889m**
Total			**$40,291m**

Capital and Operating Costs (NPV) **- Option Two – *Busway with full Stations and Park'n' Ride***

	Do Minimum	***Option Two***	***Option Two net costs***
Capital Costs	0	$41,331m	**$41,331m**
Maintenance	0	$5,354m	**$5,354m**
Funding gap	$36,072m	$75,602m	**$39,530m**
Total			**$86,215m**

The benefit to cost ratio or the Efficiency Ratio as it is described in the ATR is calculated in the table below

	Benefits to existing PT users	
	Bare Stations	***Full Stations***
Benefits	$119,218m	$177,115m
Costs	$40,291m	$86,215m
E/R	**2,96**	**2,05**

Under Transfund's funding criteria, this project would not qualify as the E/R would need to be above 4,0. Accordingly, it fell with the ambit of Infrastructure Auckland, and because the E/R was comfortably above 1,0 the project was accepted.

9. Conclusion

This study is one of the few, if not the only, projects in New Zealand where a major public transport facility has been proposed that relied on the provision of road infrastructure. Clearly, had the Busway been proposed as a dedicated public transport facility, it would never have met the funding criteria of Transfund. However, the introduction of HOV vehicles brought the carriageway component into Transfund's arena, and the Busway component 'piggy backed' on that, but used improvements to existing and future bus passengers, coupled with 'decongestion' benefits to justify the additional expenditure on station linkages and facilities.

As a consequence, the analysis was much more complicated than a standard project evaluation, different objectives of the stake-holders also added to the complexity, and the division of work between two consultants did not make the analysis any easier, although it probably gave confidence in the results because of the need for consistency.

The analysis technique, although not the study team's first choice, proved adequate for this project, but by its nature, it is difficult to use in areas which are rapidly expanding. Forecasting of public transport trips relies on growth factor techniques which do not adequately deal with new public transport corridors or developing areas where there are no present day services.

Following the presentation of the results to Infrastructure Auckland in November 2001 over NZ$50 million (R245 million) funds have been approved towards implementation for this BRT project.

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Grant has been with Gabites Porter since September 1975 following three years in the UK. He has practiced as a consultant in New Zealand, Australia & Malaysia, advising Local, Regional and Central Government, as well as private clients. Grant has undertaken transport planning studies in almost every city in New Zealand, and in many of the cities in New South Wales, Queensland, in Australia and Malaysia. His areas of expertise are in the modelling of urban and rural systems, economic & financial evaluation, public and private transport demand forecasting, and computer design and applications. He has also served as expert witness in the Environment Court. He has been instrumental in developing TRACKS -a transportation model widely used in Australasia. In particular he is one of the few people in New Zealand to have been involved in the building of both conventional models, and disaggregate models from recent survey data. He has authored & presented over 14 papers and written 4 research reports.